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CDC 30353

AUTOMATIC TRACKING RADAR SPECIALIST

(AFSC 30353)

Volume 1

Maintenance Management and Test Equipment

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Air University

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Prepared by
MSgt Kenneth J. Hutchinson
(AUTOVON 868-4539)

Reviewed by
Pamela G. Brown

Edited by
David Crawford

USAF TECHNICAL TRAINING SCHOOL (ATC)
KEESLER AIR FORCE BASE, MISSISSIPPI 78843

EXTENSION COURSE INSTITUTE (AU)
GUNTER AIR FORCE STATION, ALABAMA 36118

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Preface

THIS FIRST VOLUME of CDC 30353 is composed of eight chapters that will acquaint you with subjects you need to become very familiar with in order to be an effective maintenance specialist. Understanding how to advance in your career field is explained in Chapter 1. Production and control of Air Force property is covered in Chapter 2. Chapter 3 deals with security. To aid you in understanding Air Force publications, you will find that Chapter 4 contains useful information. The many sections and staff offices involved in CEM maintenance management are discussed in Chapter 5. Chapter 6 covers maintenance safety, preventive maintenance, and other practices that are designed to enhance your system's reliability. Chapter 7 will acquaint you with some of the tools and techniques that help you with soldering. Test equipment is discussed in Chapter 8.

Foldouts 1 through 4 are bound in the back of this volume.

Code numbers appearing on figures are for preparing agency identification only.

The inclusion of names of any specific commercial product, commodity, or service in this publication is for information purposes only and does not imply indorsement by the Air Force.

NOTE: If you know this course contains erroneous or outdated information or does not provide the knowledge that the current Specialty Training Standard (STS) requires you to have for upgrade training, contact your OJT advisor and fill out AF Form 1284, "Training Quality Report." If you need an *immediate* response to subject matter questions while you are studying this course, call the author between 0700 and 1600 CT, Monday through Friday.

Consult your education officer, training officer, or NCO if you have questions on course enrollment or administration, Your Key to a Successful Course, and irregularities (possible scoring errors, printing errors, etc.) on the Volume Review Exercises and Course Examination. Send questions these people can't answer to ECI, Gunter AFS AL 36118, on ECI Form 17, Student Request for Assistance.

This volume is valued at 24 hours (8 points).

Material in this volume is technically accurate, adequate, and current as of January 84.

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Acknowledgement

ACKNOWLEDGEMENT is gratefully given to PACE Incorporated, Non-Linear Systems Incorporated, Tektronix Incorporated, and Hewlett-Packard Company for permitting text and illustrations from their Instruction Manuals to be used in this CDC. Our discussion of the PACE Electronic Maintenance System in Chapter 7, Section 7-8, is based on the PACE Instruction Manual.* The information concerning the LX-2 Digital Voltmeter in Chapter 8, Section 8-2, is based on its Instruction Manual provided by Non-Linear Systems Incorporated.** The text relative to the Tektronix-Type 453 Oscilloscope in Chapter 8, Section 8-4, is based on the Manufacturer's Instruction Manual provided by Tektronix Incorporated.*** The information covering the HP 432A Power Meter in Chapter 8, Section 8-7 is based on the Operating and Service Manual, Power Meter 432A, provided by Hewlett-Packard Company.**** Each of these identified areas is used with the permission of PACE International, Non-Linear Systems Incorporated, Tektronix Incorporated, and Hewlett-Packard Company respectively.

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**Manual for Electronic Maintenance System, Model PRC-350C.* Pace, Inc., 9893 Brewers Court, Laurel, Maryland.

***Instruction Manual, Series LX-2, Digital Multi-Function Meter.* Document No. 1430, Revision B, Feb. 1972. Non-Linear Systems, Inc., Del Mar (San Diego), California.

****Instruction Manual, Type 453/R453 Oscilloscope (above SN 20,000).* Tektronix, Inc., S.W. Milikan Way, P.O. Box 500, Beaverton, Oregon.

*****Operating and Service Manual, Power Meter 432A.* Hewlett-Packard Company, 120 Century Blvd., New Jersey 07652.

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NOTE: This course teaches through numbered lesson segments, each containing a behavioral objective, text, and exercises. The objective sets your learning goal. The text gives you the information you need to reach that goal, and the exercises let you check your achievement. When you complete each segment, see whether your answers match those in the back of the volume. If your response to an exercise is incorrect, review the objective and its text.

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Career Field Progression

CONGRATULATIONS! You have successfully completed the basic technical school course and have been awarded an Air Force Specialty Code (30333), an Automatic Tracking Radar Specialist, semiskilled level.

You are now entering a self-study phase so that you can get the necessary knowledge and thus be awarded the 5 skill level in your Air Force specialty. As you begin your study of this CDC, keep in mind the following quote from AFR 35-1, *Military Personnel Classification Policy:*

> Individual Responsibility. An Air Force member's career progression is directly related to the amount of personal effort made to gain and keep specialty qualification. Accordingly, specialty knowledge and proficiency are primarily the responsibility of each individual. Several programs that blend specialty training with academic pursuits are available through Base Education Service Centers (for example, Community College of the Air Force). Each officer and airman is encouraged to use every opportunity available that would enhance individual technical, military, and professional qualities.

In view of the preceding quote, you see that the successful completion of this CDC is one of your responsibilities toward your career progression. As you study this chapter, you will learn other responsibilities.

1-1. Progression in Career Ladder 303X3

Your main question at this time is probably, "How do I progress up the career field ladder?" Actually, you have already started. Successful completion of the basic course was step one in your career progression. Now let's see what upgrade requirements you must meet if you are to progress to the 5 level.

001. Given a list of upgrade requirements, select those that are mandatory for the award of AFSC 30353.

Changes or awards of an AFSC are based on standards from AFR 39-1, *Airman Classification Regulation,* and information from AFR 35-1. These standards are prescribed in paragraph 3 (Specialty Qualifications) of each specialty description. There are mandatory and desirable requirements in *knowledge, education, experience, training,* and *other.* Mandatory requirements are minimums for the award of an AFSC. Desirable requirements aid in your ability to work in your AFSC. The following is an extract from your specialty description. It shows both the mandatory and desirable requirements for the award of the 5 level in your AFSC.

3. SPECIALTY QUALIFICATIONS

a. Knowledge. Knowledge of the following is mandatory: electronic principles, including theory of transistors and solid-state components, that apply to acquisition and automatic tracking systems; associated data processing systems, related to electronic warfare equipment operation and maintenance; interpretation of technical orders; and engineering wiring and schematic diagrams. Possession of mandatory knowledge will be determined according to AFR 35-1.

b. Education. Completion of high school with courses in physics and mathematics is desirable.

c. Experience. Experience is mandatory in functions such as testing, calibrating, operating, maintaining or repairing acquisition and automatic tracking systems, and using electronic test equipment.

d. Training. Completion of basic automatic tracking radar maintenance course is desirable.

e. Other.

(1) Normal color vision sas defined in AFR 160-43, *Medical Examination and Medical Standards,* is mandatory.

(2) A Secret-security clearance is mandatory for award and retention of the semiskilled and skilled AFSCs.

The mandatory requirements of items 2*e* were met before you were assigned to your 3-level training in the automatic tracking radar specialist course.

Other mandatory requirements for the award of an AFSC are set forth in AFR 35-1. This regulation shows that to be awarded a 5-level AFSC, you must have:

a. Satisfactorily performed in the 5-level AFSC for 6 months.

b. Successfully completed all training requirements (this CDC is one of them).

c. Been recommended for upgrading by your supervisor.

d. Met other mandatory requirements or equivalents.

Certain substitutions for the mandatory requirements are authorized by AFR 35-1. For example, if you had a previous assignment to an authorized position in the AFSC, it could be counted as part or all of the mandatory 6 months' experience required. If you are interested in the authorized substitutions, refer to AFR 35-1.

Exercise (001):

1. From the following list of upgrade requirements, select those that are mandatory.
   a. Knowledge of electronic principles including theory of transistors and solid-state components.

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b. Knowledge of blueprints, wiring diagrams, and schematic drawings.
c. Completion of high school.
d. Experience in using electronic test equipment.
e. Completion of automatic tracking radar maintenance course.
f. Satisfactory performance at the 5 level for 6 months.
g. Possess a Secret security clearance.

1-2. Duties of the 5-Level AFSC

In your case you were awarded the 3-level AFSC upon graduation from the basic automatic tracking radar maintenance course. As soon as you were assigned to a using organization, you were placed on upgrade training to the 5-level AFSC. Now, although you hold a 3-level AFSC, you are performing 5-level duties. Later on, in your career, you will perform duties as a 7 level and, we hope, make it to the 9 level. But, let's look at your duties now, and see how they compare with the 7- and 9-level AFSC duties.

002. Considering the type of duties performed at the various skill levels of AFSC 303X3, identify the skill level with a given duty.

The duties and responsibilities for the 5-level automatic tracking radar specialist are given in paragraph 2 of the specialty description. This paragraph is quoted as follows:

2. DUTIES AND RESPONSIBILITIES

a. Performs preventive maintenance on acquisition and automatic tracking systems. Inspects and tests automatic tracking radar equipment at specified intervals to locate defective components and broken or missing hardware. Adjusts or replaces defective components. Turns on equipment, sets controls in appropriate operating positions, and evaluates equipment performance, using applicable test equipment. Performs corrosion control as required.

b. Installs acquisition automatic tracking systems. Inspects equipment for serviceability before installation. Assembles and connects equipment. Conducts detailed tests of installed equipment for proper assembly of components and compliance with technical orders. Places in operation and tunes, adjusts, and aligns components to obtain maximum operating efficiency.

c. Operates acquisition and automatic tracking systems. Controls aircraft or drones/remotely piloted vehicles during aerodynamic missions. Identifies and tracks target aircraft or drones. Computes and plots impact points. Observes equiment performance while operating automatic tracking equipment used in electronic warfare and radar bomb scoring/directing operations.

d. Maintains acquisition automatic tracking systems and associated equipment. Isolates malfunctions by standard system-checking procedures using specialized electronic test equipment. Repairs automatic tracking system components according to technical orders, manufacturer's handbook and local procedures. Accomplishes routine modification of equipment according to modification work orders and field directives. Performs progressively more difficult repair duties as specifically directed by chief of maintenance.

e. Maintains operation logs and maintenance and inspection records. Posts entries on applicable maintenance and inspection records. Records significant data on equipment historical forms. Completes maintenance data collection forms. Recommends methods to improve equipment performance and maintenance procedures. Records pertinent data incident to missions involving aircraft, drones/remotely piloted vehicles.

f. Supervises automatic tracking radar repair personnel. Assigns work and reviews completed repairs to insure compliance with local procedures and applicable technical publications. Instructs subordinates in techniques of installation, operation, maintenance, and repair of assigned equipment. Insures personnel are aware of appropriate procedures prescribed by USAF maintenance management directives.

If you were to look at paragraph 2 of the 30373 specialty description in AFR 39-1, you would find the headings as follows:

a. Resolves technical problems encountered during siting, installation, operation, repair, and overhaul of acquisition and automatic tracking systems.
b. Repairs, overhauls, modifies, and installs acquisition and automatic tracking systems.
c. Operates acquisition and automatic tracking systems.
d. Inspects acquisition and automatic tracking systems.
e. Supervises automatic tracking radar repair personnel.

Notice that most of the headings (*a, b,* and *c*) are quite different from those in the 5-level specialty description. Although heading *e* of the 7 level reads the same as heading *f* of the 5 level, the material under the heading is quite different. The 5 level is responsible for conducting OJT, supervising subordinates, and insuring awareness of maintenance management directives. But the 7 level is responsible for such items as planning and scheduling work assignments; establishing work methods, production controls, and performance standards; insuring availability of maintenance equipment, tools, and spare parts; establishing work priorities; and evaluating performance of repairmen.

The 9-level AFSC responsibilites deal with such items as planning and organizing ground radar maintenance activities. Notice, we said, *ground radar.* The 9 skill level is classed as a 30399 and can be assigned to an aircraft control and warning radar (AC&W) activity, an Automatic Tracking Radar activity, or an air traffic control radar activity.

In this CDC, we have given you a brief outline of the 7-level and 9-level AFSC duties so that you can see where you fit into the picture as a 5-level specialist. If you are interested in the complete job description for the 7 and 9 levels, you can find them in AFR 39-1.

Exercises (002):

1. At which skill level would you most likely be concerned with planning and scheduling work assignments?

2. At which skill level would you most likely be concerned with isolating a malfunction by using standard system-checking procedures?

3. At which skill level would you most likely be concerned with inspecting automatic tracking radar equipment?

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1-3. Dual-Channel Concept of OJT

Earlier in this chapter you learned that this CDC is one part of your upgrade training. Now you are ready to learn the concept of OJT. OJT is defined as a planned training program designed to qualify you through self-study and supervised instruction. It is developed so that you can do this while working in an actual duty assignment. The dual-channel program consists of two parts—career development and job proficiency development.

003. Given a training situation, identify the items that are part of the CDC and those that are part of the JPG.

Career Development Courses (CDCs). CDCs contain information on broad career field theory, fundamentals, basic principles, and common knowledge requirements for each specialty. A CDC does not teach task proficiency, and it is now practicable to teach each specific knowledge related to a task. Specific equipment or procedure knowledge is included only when it applies throughout the career field or when it is necessary to illustrate the application of a principle.

This CDC will provide the upgrade knowledge requirements for you to progress from the 3 to the 5 level. Normally, you are expected to complete your upgrade training to the 5 level within 12 months, although the training period may be extended to as much as 18 months. Once you have completed your 5-level training and have been promoted to E-5, your supervisor initiates the paperwork to enter you into OJT for the 7 level. This includes your enrollment in the 7-level CDC.

Let's take a look at this CDC and get an idea of what is covered in the way of knowledges. Figure 1-1 shows a portion of the Specialty Training Standard (STS) 303X3. Notice that item 9b(3), block diagram and schematic analysis of identification equipment, shows a knowledge level of B at the 3 skill and the 5 skill level and a knowledge level of C at the 7 skill level. The coding of this item with a capital letter indicates that only subject knowledge is required. You will find the required knowledge on this item in CDC 30373.

Now take a look at item 11a(1) in figure 1-1. At the 5 level this item is coded 3c, showing that you require knowledge. The CDC covers repair or replacement of parts in general terms. You are expected to apply the knowledge obtained to your specific job situation. You will find that we do not go through task performances in a step-by-step procedure. When you perform the task as part of your training provided by the Job Qualification Standard (JQS), you must follow the procedures in the applicable technical order and not the CDC.

All airmen in upgrade training are required to enroll in the appropriate CDC if one exists. Successful completion of the course examination (CE) for the CDC is mandatory. These requirements must be met before you can be recommended for upgrading. If you should fail the CE on your first attempt, you are permitted to retest. If you fail the retest, your commander may waive the requirement for successful completion of the CDC. However, before your commander grants a waiver, he will undoubtedly evaluate your knowledge and provide you with additional training. Once your supervisor and commander have determined that you are qualified, you will be upgraded. Now let's take a look at the other part of your training, the JQS.

Job Qualification Standard (JQS). The second part of the dual-channel concept provides for you the required job training. Job qualification training provides the skill necessary to perform tasks associated with a specific job assignment. It is the practical "nuts and bolts" work involved in the maintenance of the automatic tracking radar equipment at your duty station. The JQS is usually nothing more than an annotated STS. Let's refer to figure 1-1 again and look at item 11a(9). This item shows that in order to qualify for the 5 level, you must demonstrate the correct procedures in the boresighting, collumination, and orientation to a code level of 3. Your trainer should identify this item by circling the paragraph number in column one of the STS, and entering the training start date in column 3B in pencil. When you have completed your training on the item to the satisfaction of your supervisor, the date completed, your initials, and your supervisor's initials should be entered in column 3C.

There may be task requirements of your current duty position not identifiable on the current STS. If this condition exists, your trainer will attach an AF Form 797, Job Qualification Standard Continuation Sheet, to the STS. On this form your trainer lists whose unidentified tasks that you are required to perform in your present duty assignment. When you complete each one of these items on an AF Form 797, they are signed off in the same manner as on the STS. Any time you want to see your JQS, you will find that it is in, and part of, your AF Form 623, On-the-Job Training Record. See foldout 1.

Exercises (003):

1. One of the items on the STS calls for you to use the AN/UPM-10B radar test set. Would you expect to learn the system connections in the CDC or as part of the JQS?

2. During your training, you are required to troubleshoot the beacon system and isolate a malfunction to a system component. In order to do this, you must: (1) Connect the test equipment to the beacon system, (2) use the test equipment, (3) conduct a performance check of the system; (4) analyze the results of the performance checks to determine the malfunction. Which one of these items would you expect to learn from the CDC?

1-4 Graduate Evaluation

004. Name the types of graduate evaluation and point out the supervisor's responsibility in the graduate evaluation program.

Graduate Evaluation. The Air Force has established a program to evaluate graduates of the various technical

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schools. The program is outlined in AFR 50-38, *Field Evaluation of Education and Training Programs.* The purpose of this program is to improve personnel management courses and formal training programs.

The evaluation system is divided into two parts: (1) field evaluation visits and (2) direct correspondence questionnaires. Field evaluation visits are performed by representatives of the training activity. They visit the using agencies about 3 to 6 months after the gradute has been assigned. In the second method of evaluation, you, as a supervisor, enter into the picture. You are requested to fill out a direct corredence questionnaire for the school graduates assigned to your unit. You observe the performance of the school graduates in the normal work situation as they perform the tasks

STS 303X3

1. TASKS, KNOWLEDGES AND STUDY REFERENCES	PROFICIENCY LEVEL, PROGRESS RECORD AND CERTIFICATION								
	2. 3 Skill Level			3. 5 Skill Level			4. 7 Skill Level		
	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainee's Supervisor's Initials	A AFSC	B Date OJT Started	C Date Completed & Trainee's Supervisor's Initials	A AFSC/Crs	B Date OJT Started	C Date Completed & Trainee's Supervisor's Initials
9. AUTOMATIC TRACKING RADAR AND ASSOCIATED EQUIPMENT									
SR: TO 31-1-141 Series; Applicable System Technical Orders									
a. Principles, functions, requirements, and physical and electrical characteristics									
(1) Automatic tracking radar	B			C			C		
(2) Analog computers and digital readout systems	B			C			C		
(3) Identification equipment	B			C			C		
(4) Closed-circuit television	B			C			C		
(5) Associated electronic warfare equipment	A			B			C		
b. Block diagram and schematic analysis									
(1) Automatic tracking radar	B			B			C		
(2) Analog computers and digital readout systems	B			B			C		
(3) Identification equipment	B			B			C		
(4) Closed-circuit television	B			B			C		
(5) Associated electronic warfare equipment	A/-			B			C		
11. ALIGNMENTS, ADJUSTMENTS, AND PERFORMANCE CHECKS OF AUTOMATIC TRACKING RADAR AND ASSOCIATED EQUIPMENT									
SR: TO 31-1-141 Series; Applicable Systems Technical Orders									
a. Radar systems									
(1) Power supplies	2b			3c			4c		
(2) Transmitting systems	2b			3c			4c		
(3) Receiving systems	2b			3c			4c		
(4) Synchronizing systems	2b			3c			4c		
(5) Range computers	2b			3c			4c		
(6) Range tracking systems	2b			3c			4c		
(7) Presentation systems	2b			3c			4c		
(8) Antenna positioning	2b			3c			4c		
(9) Boresighting, collimation, and orientation	2b/b			3c			4c		
b. Computer systems									
(1) Power supplies	2b			3c			4c		
(2) Servosystems	2b			3c			4c		

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Figure 1-1. Portion of Specialty Training Standard.

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listed in the STS. You record your daily observations in terms of their performance and the supervision they require.

Since these evaluations are needed to pinpoint the ability of graduates to perform the tasks they were trained to do, you should be as accurate in your evaluations as possible. The forms you receive are designed so that you can compare the graduate's performance of tasks with the performance level shown in the STS. In most cases, the performance level for the course and the 3-level AFSC are the same. Howver, the formal course is not capable of teaching some items to the desired level. In these cases, compare the graduate's performance with the course level code. Be sure that you properly indicate the STS items that are not performed or not required. If you have not had a chance to have the graduate perform an STS task, indicate it as "Not performed" on the questionnaire. If a particular STS task is not required in your unit, the questionnaire should indicate "Not required." For example, one of the items on the current STS states that a graduate is trained to the 2b level in making alignments to microwave systems. If your unit is not responsible for the maintenance of an RML, you indicate "Not required" for this STS task.

If a graduate does not satisfactorily meet all of the training codes listed in the STS, you should prepare an AF Form 1284, Training Quality Report (TQR). Submit this form to ATC and to the technical training center that sent out the questionnaire. Remember, your accuracy in answering the questionnaire and submitting AF Form 1284 aid in improving the technical training courses.

Exercises (004):

1. What are the two parts of the evaluation system?

2. What should you use as a standard when you are filling out a graduate evaluation questionnaire?

3. What form should you use to report a graduate whose training is not up to standard?

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Production and Property Control

2-1. Production Control

Production controls include mechanical and graphical standards, time budgeting, and work scheduling. Mechanical standards are largely determined by your AFSC, the STS, and the types of tools and test equiopment required on the job. Graphical standards can be prepared at the shop or at higher levels with specially designed forms and graphs. A chart can show you at a glance what jobs your people are working on, how the jobs are progressing, the radar and systems involved, etc.

005. List main principles in the determination of the actions necessary to insure continuous high-quality production.

Performance Standards. One of the biggest problems you face is the determination of performance standards. To insure your personnel meet their objectives, you must set standards for them. In some cases the standards are handed to you from higher authority. In others you are faced with devising standards of your own to fit the job.

A supervisor must know the capabilities of his or her personnel. Just as important, each person must know what is expected of him or her. Wise use of performance standards will greatly reduce confusion and will improve work quality in your section. During your daily activities you should look at your area and make sure that your people are meeting the standards.

In the event an area is falling below standard, you should set up a program to get it back to standard quickly. You noticed we used the word "quickly." This is important to the supervisor. If you let something slip for a while because you have other things to worry about, the substandard condition could become accepted as the standard. All Air Force supervisors have the responsibility of supporting established performance standards.

Maintenance and Inspection Reports and Charts. Maintenance and inspection reports are very important in the job of a supervisor. He or she has many daily and monthly maintenance reports which can be used to give him or her an idea where the workers are being employed most of their time. These reports are prepared from information that is supplied on maintenance forms. In addition, the squadron analysis section keeps a complete record of all writeups from your section.

Careful analysis of these reports can help pinpoint problem areas in your equipment. An example would be: While reviewing your monthly maintenance report, you noticed a large percentage of the maintenance hours were spent on one item. Further investigation showed that the cause of the failure was always the same. With this information you should make a thorough check of the equipment involved and the procedures used to maintain it. You may find it necessary to increase training in order to insure proper maintenance, or it may be a highly technical problem requiring assistance from other sources. Proper use of maintenance reports can identify trends that could cause serious problems in the future if not corrected as soon as possible.

Charts and graphs are often useful to the supervisor as he or she compares several items against each other such as time versus failures. A word of caution here is to limit the use of the charts or graphs. They must not be so complicated that they cannot be read. A chart, such as a training chart, can have many training operations indicated and still be readable. However, if the supervisor starts adding leave schedules, annual shots, and other items that he or she wants to know about his or her people, then the training cannot be determined quickly. Graphs are limited more than charts. If we are to be able to read and understand a graph, it should be limited to not more than five items.

Organizational and Functional Charts. The time to start establishing good employee relations is during your newcomer's briefing. You can use the organizational chart during this briefing to show the individuals how they fit into the support of the squadron mission.

Normally, an organizational chart shows one level of supervision above and two levels below the charted position. One above your position would be your supervisor. The one below you would be your assistant and below that perhaps would be the team chiefs. The above example is purely hypothetical.

A more detailed briefing in each position can be given with the use of a functional chart. The functional chart will be much like the organizational chart, except the duties and responsibilities of each position will be listed on the functional chart. If may also list job descriptions and Air Force publications required to accomplish the assigned task.

Exercises (005):

1. Why should a supervisor correct substandard performance quickly?

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2. When should the supervisor check to make sure the people are meeting the standards?

3. How may the supervisor identify problem areas developing in the equipment?

4. What precaution must be taken when using charts and graphs?

5. How may the supervisor use the organizational chart to help establish employee relations?

6. Which one of the charts discussed in the text would you use in explaining the duties and responsibilities of each position?

2-2. Property Control

To accomplish the mission of the Air Force we have many thousands of items. Among these are spare parts, special tools, maintenance equipment, pencils, paper clips, and other items. The cost runs into billions of dollars. This property is stored, issued, re-issued, and sometimes lost or destroyed. Here we will discuss some of the controls and responsibilities for Air Force property.

006. Describe the main principles governing supply authorization and the management of expendable supplies.

Supply Authorization. The equipment authorized for your unit is based on two general factors—the unit mission and the number of people. These factors are interrelated; for example, if performance of the mission requires certain vehicles, then operator personnel must be authorized and quantities of other items of equipment based on the number of people who are affected.

The equipment authorized your unit is based on USAF allowance documents. These documents reflect the average minimum quantities of equipment items needed to accomplish the mission. However, the allowance documents do not necessarily reflect the exact quantities your unit will be authorized. Exact quantities are determined by major commands and base equipment management offices. They're influenced by such factors as the number and types of equipment to be maintained, the type of maintenance performed, the number of personnel, and the climatic conditions.

Tables of allowance (TAs). The USAF tables of allowance are the authorization sources quoted in requests for issue. They provide a list of equipment in the quantity normally required by the mission of an Air Force activity.

TAs can be used to authorize additional equipment. For example, the equipment you now have could be replaced with a new and different type of equipment that requires additional test equipment. In this case you would quote the applicable TA as authorization for the additional test equipment.

Expendable supplies. These are items which are either consumed or lose their original identity by incorporation into another assembly. Office supplies such as paper and pencils are examples of items consumed in use. Bench stock items, such as nuts, bulk hose, seals, and repair kits are items which are incorporated into another assembly.

Bench stock is a working stock of nonrecoverable items. It is required to provide uninterrupted operation and expedite maintenance. One shop bench stock may be authorized for each maintenance shop area, or the bench stock may be combined when two or more shops occupy the same area.

Transactions with A&A and MSS. A&A, or Allowance and Authorization, is responsible for control of the base equipment management system. So far as your unit is concerned, A&A is the source of supply. Also, it receives all equipment requests for nonexpendable items listed on the TA for your organization. Examples of these items are tools, machines, and clothing.

MSS, or the Material support section, controls and issues repair parts and maintenance items. These items fall into two categories: (1) bench stock, which consists of miscellaneous items of expendable hardware, and (2) repair cycle items. MSS also issues local purchase items, such as pencils and paper clips.

For requesting supplies you will most likely find local and Air Force forms used. For this reason we will not discuss the form numbers. We will list some of the information that will be required by them. Keep in mind that these forms have a dual purpose; they are used for either issue or turn-in of equipment or supplies. Turn-in is appropriate for excess or unserviceable property. Your unit supply custodian will indicate which action is required. Now let's see what type of information goes on the form.

- Date of request and unit designation.
- A unit supply request number (for identification or followup action).
- The name and telephone number of the unit supply custodian.
- Equipment stock number or part number and name or description of the item.
- Justification of request. This will include citing the allowance documents applicable and a brief statement of circumstances.
- The quantity required.
- A certificate by the commander or his or her representative that the requirement is valid.

Exercises (006):

1. What factor is involved in determining what equipment may be authorized by a TA?

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2. The USAF allowance documents reflect the average minimum equipment needed to accomplish the mission. Who determines what quantities are issued?

3. Describe why a bench stock item is stocked.

4. Describe expendable supplies.

5. Who handles the equipment request for nonexpendable items listed in the TA for your organization?

007. Describe methods that are normally used to release a custodian from property responsibilities for lost, stolen, or damaged equipment when there is negligence and carelessness indicated.

Lost, Damaged, or Destroyed Property. The monetary loss to the Air Force must be accounted for in some manner when property is lost, damaged, or destroyed. The person(s) with responsibility for the property may have to reimburse the Air Force. If not, the Air Force will have to sustain the loss.

Two methods of being relieved of property responsibility involve the use of a "cash collecting voucher" and a "statement of charges." These two forms are used to reimburse the Air Force when pecuniary liability is admitted. The damage to, or the list price of, the article cannot exceed $500 to use these methods. Keep in mind that even though the individual has paid for the loss, the property does not become the property of the individual.

The least troublesome way to settle a monetary obligation is to pay in some form of cash. The Cash Collection Voucher, DD Form 1131, is generally prepared by the responsible officer to cover the cash collections for a particular period of time. Listed on the cash collection voucher are the names of the airmen, the articles lost or damaged, and the amounts involved. The voucher shows the complete Air Force description of the items involved and the purpose for which collection was made. Negligence and carelessness may be indicated as the causes of damage to the property. The statement "Used in Lieu of Report of Survey" is an indication that pecuniary liability has been admitted. Before the money is turned in to the finance office, the cash collection voucher must be approved by the individual's commander. Cash collection vouchers are sometimes prepared by supply personnel. What do we use to make the payment if we do not have the money with which to pay?

Airmen and civilian employees use the DD Form 362, Statement of Charges for Government Property Lost, Damaged or Destroyed, when pecuniary liability is admitted but a payroll deduction is desired. This is in lieu of a cash payment. Like the cash collection voucher, the damaged item's price cannot exceed $500. The individual(s) is(are) charged the cost of the articles or allowed up to 25 percent depreciation. This is why the actual cost may be less than the prices listed in the top section of the form. When the individual signs a statement of charges, he or she has made an acknowledgement, an authorization, a waiver of a right, an affirmation, and an agreement. The commander must certify this form before it is submitted for a payroll deduction.

If an officer admits liability and cannot pay with cash, he or she uses DD Form 114, Military Pay Order. This authorizes a deduction from his or her pay for the amount involved.

Exercises (007):

1. Identify the two forms used by the Air Force to be reimbursed for lost, damaged, or stolen property valued at or below $500 listed price.

2. Explain why there might be a price of $200 listed at the top of a statement of charge form and a $185 price listed at the bottom.

3. What are some of the things an individual agrees to when he or she signs a statement of charges form?

008. Explain the purpose of the report of survey.

Report of Survey. A report of survey is an instrument for explaining and recording the circumstnaces which involve loss, damage, or destruction of Air Force property. When used, it supports the dropping of property from the records. It also serves to resolve the questions of responsibility for loss and it fixes liability. In summary, when one individual will not admit liability or when the amount to be charged is over $500, a report of survey must be prepared.

Preparing the report of survey form is the first step in the report of survey process. The individual who has custodial responsibility for the property starts the process. A provision has been made for others to perform this duty for him or her. This is only when it is impractical for the custodian to fill it out. Since the report of survey is a means for explaining the loss, damage, or destruction of Government property, the responsible individuals should include all pertinent facts and circumstnaces surrounding the loss. It's important that reports of survey be initiated and processed within 30 days of the date the loss was discovered. The investigation must be made while the persons involved, including witnesses, are available and facts are still fresh. After the report is complete, it goes to the base appointing authority for review and appropriate action.

If the report of survey is approved, the individual will be relieved of the pecuniary responsibility of the individual equipment. He or she need not reimburse the Air Force for the cost of the item. Howver, if the authorities decide the

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individual was negligent, he or she will have to reimburse the Air Force.

Exercises (008):

1. What is the purpose of the report of survey?

2. Who prepares a report of survey?

3. What is the maximum delay allowed after a loss is discovered before a report of survey must be initiated?

009. Identify methods used to justify personnel and equipment.

Justification for Equipment and Manpower. Justification for personnel and equipment was briefly discussed earlier in this chapter. You already know that to accomplish the mission you must have the necessary equipment and manpower. In today's Air Force, radar systems are being modified every day. Some systems may be removed, improved, or replaced with a completely new system. This may affect your manning and required maintenance equipment. Excessive overtime required to support the mission may indicate undermanning or lack of training. There are many areas that you must look at very closely as you justify personnel. For a starting point, look at the unit's mission. Are you accomplishing tasks normally assigned to other sections? Has your operational hours increased because of additional wing flying hours? Are these going to be temporary or permanent conditions? Also check the unit manpower document (UMD) to see how many people are authorized. The UMD may authorize more people than are assigned at the present time. It should be brought to the attention of the commander that the mission cannot be supported properly.

Before additional equipment and personnel can be authorized, you must have all the facts. The commander normally keeps close watch over his or her manning and equipment authorization. It is possible, however, that you may supply one small fact that may be justification for emergency manning or reassignment of work to other sections. The same is true of equipment. Replacement of faulty equipment or that which is in limited supply and hard to repair may be justified. The commander may want to review the facts with you to insure that he or she has all the necessary information clearly in his or her mind before going to higher levels of command for help.

Exercises (009):

1. List those conditions that may affect manning and equipment authorization.

2. Why may the commander wish to review your facts?

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CHAPTER 3

Security Programs

LIKE SAFETY, security is a topic that applies to each of us all of the time. The word "security," of course, refers to the protection of Air Force information and materials. This protection is designed to provide for the Air Force the freedom and secrecy necessary to accomplish our part in the national defense.

The fact that you do not handle items marked "classified" does not mean that you are exempt from taking part in the security program. In fact, those who seldom work in a security atmosphere may be the most vulnerable to another nation's collection of facts related to Air Force operations. Consequently, this text discusses the information, industrial, communications, and operational security programs. It also deals with the basic protective measures associated with Air Force resources and the Department of Defense (DOD) U.S. Secret Service (USSS) agreement concerning protection of our Commander in Chief, the President.

Although each of the security programs is shown as a separate entity, they are closely related. In fact, in many instances, you will see that the security actions overlap. The purpose of such interaction and overlap is simple: to deny a potential enemy information about completed, current, or planned operations, resources, and activities.

3-1. Information and Industrial Security Programs

The United States must protect against hostile, destructive, or subversive action. To do this, certain official information affecting the national security must be protected. This is done to keep unauthorized persons or agencies from obtaining it. At the same time, U.S. citizens must be kept informed of the activities of their Government. Therefore, information may be withheld only when necessary in the national interest, and it must be removed from any security system as soon as that protection is no longer warranted.

The information and industrial security programs were established by order of the President and implemented through normal command channels. In these programs all individuals are responsible for protecting classified information they possess. All supervisors are responsible for protecting the information they have, and for supervising implementation of applicable security systems. All Air Force personnel who have knowledge of, or access to, classified information must be familiar with the security directives that apply to them in the performance of their duties.

010. State the individual's responsibilities in the information security program, and list the minimum security education requirements.

Individual Responsibilities. Security is the sum total of each individual's adherence to and compliance with sound protective practices. Adequate security can be obtained only by sound direction from supervisors, coupled with alert performance of duty by each member of the Air Force. You are responsible for familiarizing yourself with, and adhering to the provisions of the regulations and supplementary instructions which apply to your assigned duties; protecting and accounting for all classified information you know or possess, regardless of how you obtained it; and making sure that any document you sign or that any instruction you give does not require, authorize, or imply an action in violation of information security policies.

Security Education. Security education programs will be provided for all personnel authorized or expected to be authorized access to classified information. The program should be designed to fit the requirements of different groups of personnel. The program, as a minimum, is designed to:

a. Advise personnel of the adverse effects to the national security that could result from unauthorized disclosure and of their personal, moral, and legal responsiblity to protect classifed information within their knowledge, possession, or control.

b. Indoctrinate personnel in the principles, criteria, and procedures for the classification, downgrading, declassification, marking, and dissemination of information, as prescribed in the regulation, and alert them to the strict prohibition on improper use and abuse.

c. Familiarize personnel with procedures for challenging classification decisions believed to be improper or to prolong classification unnecessarily.

d. Familiarize personnel with the security requirements of their particular assignment.

e. Inform personnel of the techniques employed by foreign intelligence activities in attempting to obtain classified information and their responsibility to report such attempts.

f. Advise personnel of the penalties for engaging in espionage activities.

g. Advise personnel of the strict prohibitions against discussing classified information over an unsecure telephone or in any other manner that permits interruption by unauthorized persons.

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h. Inform personnel of the penalties for willful violation or disregard of the provisions of DOD 5200.1-R/AFR 205-1.

i. Brief personnel on the requirements concerning the compromise of classified information and administrative sanctions contained in Chapter VI and XIV of DOD 5100.1-R/AFR 205-1.

j. Instruct personnel that individuals having knowledge, possession, or control of classified information must determine, prior to disseminating such information, that the prospective recipient, has been checked for access by competent authority, needs the information in order to perform official duties and can properly protect (or store) the information.

Exercises (010):

1. What are your personal responsibilities under the information security program?

2. What three actions must be checked prior to the dissemination of classified information to a prospective recipient?

011. Distinguish between classified and unclassified information as related to its intelligence value.

Information of Intelligence Value. Information of intelligence value includes classified information, which is official information that must be protected from disclosure in the interest of national defense; and unclassified information, which is official information that may be harmless when considered bit by bit, but can be of intelligence value when compiled.

Classified Information. Within the Federal Government there is some official information and material which, because it bears directly on the effectiveness of our foreign relations, must be subject to some constraints for the security of our Nation and the safety of our people and our allies. To protect against both overt (obvious) and covert (hidden) actions hostile to the United States, it is essential that official information and material be given only limited dissemination. Official information or material that requires protection against unauthorized disclosure in the interest of national security is classified in one of three categories; namely, Top Secret, Secret, or Confidential. You'll learn more about these categories shortly. No other categories are used to identify official information or material that requires protection in the interest of national security, *except* as otherwise specifically provided by Federal statutes.

Unclassified information. Unclassified information is official information that may be harmless when considered bit by bit, but can be of intelligence value when compiled. Unclassified information of intelligence value includes information that is is in direct support of, or is otherwise directly associated with, classified information and which contributes to knowledge of the classified aspects of information. This category also includes unclassified information which, when associated with other unclassified information reveals an insight into, or aspects of, classified information.

There is some information that will not fit into any of the categories of classified information, but for one reason or another should be withheld from general public disclosure. This type of information is designated as "For Official Use Only." Some examples of For Official Use Only material would be:

a. Reports of proceedings to select personnel for assignments, school, promotion, retention, and similar purposes.

b. Lists identifying firms or individuals suspected under procurement regulations when the lists are compiled in connection with investigation of irregularities.

c. Inspector general reports, auditor general reports, or other reports of inspections, investigations, or surveys that pertain to safety or the internal management, administration, and operation of the Air Force, unless they reflect on classified programs.

Exercises (011):

Indicate each true statement and correct any false ones.

___ 1. Information of intelligence value includes classified and unclassified official information.

___ 2. One purpose for classifying information is its probable impact on the international relations of the United States.

___ 3. Official information which needs protection in the interest of our Nation's defense is usually unclassified.

___ 4. Unclassified information is official information such as the base telephone directory.

___ 5. Information or material which does not meet the need for security classified but is not intended for general release is considered Secret.

___ 6. According to the material in this text, generally all forms of official information can be of intelligence value.

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012. Define the security classification designations.

Classification Designations. Information or material that requires protection against unauthorized disclosure in the interest of national security should be classified in one of three designations: Top Secret, Secret, or Confidential. The marking "For Official Use Only," and "Limited Official Use" should not be used to identify classified information. Terms such as "sensitive," "conference," or "agency" should not be used in conjunction with an authorized classification designation.

Information may not be considered for classification unless it concerns:

a. Military plans, weapons or operations.

b. Foreign government information.

c. Intelligence activities, sources or methods.

d. Foreign relations or foreign activities of the United States.

e. Scientific, technological, or economic matters relating to national security.

f. United States Government programs for safeguarding nuclear material or facilities.

g. Other categories of information which are related to national security and which require protection against unauthorized disclosure as determined by the Secretary of Defense or Secretaries of military departments.

Top Secret. "Top Secret" should be applied only to information or material which, when disclosed to unauthorized sources, could reasonably be expected to cause exceptionally grave damage. This includes armed hostilities against the United States or its allies, disruption of foreign relations vitally affecting the national security, the compromise or vital national defense plans or complex cryptologic and communications intelligence systems, the revelation of sensitive intelligence operations, and the disclosure of scientific or technological development vital to national security.

Secret. "Secret" should be applied only to information or material that if disclosed to unauthorized sources could *reasonably* be expected to cause serious damage to the national security. Examples of serious damage include disruption of foreign relations significantly affecting the national security, significant impairment of a program or policy directly related to the national security, the revealing of significant military plans or intelligence operations, the compromise of significant military plans or intelligence operations, and the compromise of significant scientific or technological developments relating to national security.

Confidential. Should be applied to information or material which, if disclosed to unauthorized sources, could reasonably be expected to cause identifiable damage to the national security. Examples of identifiable damage include the compromise of information that indicated strength of ground, air, and naval forces in the United States and oversea area; disclosure of technical information used for training, maintenance, and inspection of classified munitions of war; and revealing of performance characteristics, test data, design, and production data on munitions of war.

Exercises (012):

1. Define Top Secret Information.

2. Define Secret Information.

3. Define Confidential Information.

013. Specify the purpose and use of security classification guides.

Security Classification Guides. In any action or activity where security is a factor, or access to classified information is called for, certain responsibilities are levied on the commander or other official charged with the success of the project. These respnsibilities include furnishing you with the security classification guidance for the information involved. This guidance is prepared by highly qualified people who have the needed knowledge and technical intelligence to make reasonable security classification decisions. Once these determinations are made, they are published in the form of a *security classification guide.*

Purpose. As its title suggests, a security classification guide gives you guidance. The guidance is clear, direct instructions, relevant to the most appropriate security classification of information used in a particular activity. In order to be certain that the correct information is given adequate protection, classification guidance must be detailed enough to allow you to identify the specific information involved. Conversely, the instructions must be flexible enough to permit you to apply a security classification to other information or materials developed during the lifespan of the original activity. The foregoing are the two most important reasons that you must have ready access to an appropriate security classification guide. Its use by anyone who originates classified material or information, and who is not authorized to assign an original security classification, is critical to assuring adequate protection of such information.

Use. When you make any decisions involving classified information or material, you should consult the classification guide issued for the particular activity involved. Using it in this way, a security classification guide helps you:

a. Isolate and identify each piece of information that needs to be classified.

b. Identify the specified level of classification to be applied to each piece of information and material.

c. Determine the appropriate schedule for phased downgrading and declassification action for each piece of classified information and material involved.

d. Ascertain the provisions that have been established for periodic reviews to determine the currency and accuracy of the classification, downgrading, and declassification guidance provided.

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Exercises (013):

You are assigned to a position involving the routine preparation of classified documents. You have been doing this job long enough to have become familiar with security classification guides. Complete the statement given below with each of the five options that follow it, and in each case identify each true statement and correct any false ones.

In doing your job, you have learned that a security classification guide:

___ 1. Is issued by any commander having knowledge of a plan, project, program, or project.

___ 2. Gives you guidance sufficiently detailed to enable you to isolate and identify each piece of information that needs to be classified.

___ 3. Specifies the level of classification that must be applied to each piece of information involved.

___ 4. Must be prepared by anyone involved in the development of classified documents.

___ 5. Designates the appropriate schedule for phased downgrading and declassification for each item of classified information involved.

014. Specify the markings required on classified material and where such markings are made.

Marking Classified Material. The entire purpose of the information security program is to protect official information against unauthorized disclosure. Sooner or later, most information is physically recorded in some way; thus, it can be revealed by reading or examining the material. Therefore, classification markings and security notations must be placed on all material containing classified information. These markings serve to record a classification decision and to identify what is classified and what is not. They are a warning notice to users that the item contains classified information, and they indicate the need for special accounting, transmission, and safekeeping procedures.

Each document or item of material that contains or reveals classified information must be marked to show at least four things:

(1) The identify of the original classification authority, unless he or she is the signer or approver of the document.

(2) The date of classification or office or origin.

(3) The overall classification of the document.

(4) Instructions for downgrading and declassification.

In addition, various other markings may be required, depending on the source of the classified information or the intended recipient (special access material such as NATO must bear the NATO marking).

For most documents, the overall classification will be conspicuously marked, stamped, or affixed permanently at the top and bottom of the outside of the front cover (if any), on the title page (if any), on the first page, and on the outside of the back cover (if any). Each interior page will be marked top and bottom according to its content with the highest classification contained on that page. Each section, part, paragraph, subparagraph, or similar portion of a classified document will be marked to show the level of classification of the information contained in or revealed by it, or that it is unclassified as shown in figure 3-1. For other material, the location for classification markings varies to allow for physical peculiarities of the material, but each item of classified material must be marked. For instance, classified computer tapes usually have their classification marked on the outside of the tape reel.

Exercises (014):

1. What four markings are needed on classified materials?

2. Where are classified documents marked with their overall classification?

3. Where are individual page classifications marked?

4. How are individual paragraphs of classified material marked?

015. Define access; state the requirements for safeguarding, reproducing, and destroying classified information or material; and list the actions needed when compromise is suspected.

Access. The term "access," as used in the information security program, means the ability and opportunity to obtain knowledge of classified information. This covers everything from taking physical control of classified material to being able to see or hear classified information in use by other people.

Storage or Protection Facilities. Use of classified material is limited to locations where adequate facilities are available for its storage or protection. Classified material not in use or under the direct observation of an authorized person, must be guarded or stored in an approved, locked container. These containers include file cabinets, safes, alarmed areas, and vaults.

You cannot store funds, weapons, medical security items, controlled drugs, or precious metals in any safe, security filing cabinet, or other safe-type filing container used for

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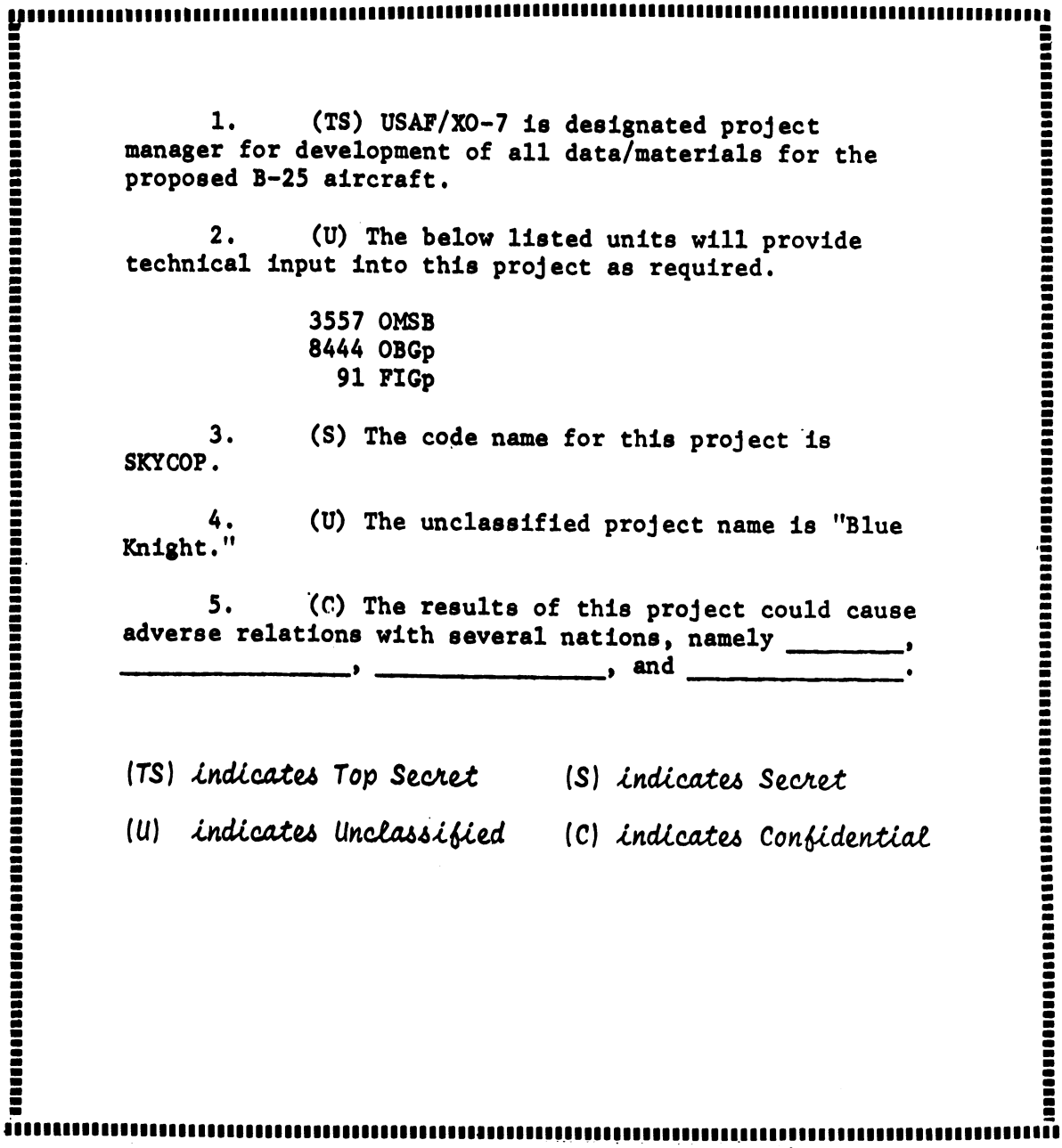
1. (TS) USAF/XO-7 is designated project manager for development of all data/materials for the proposed B-25 aircraft.
2. (U) The below listed units will provide technical input into this project as required.
3557 OMSB
8444 OBGp
91 FIGp
3. (S) The code name for this project is SKYCOP.
4. (U) The unclassified project name is "Blue Knight."
5. (C) The results of this project could cause adverse relations with several nations, namely _____, _____, _____, and _____.
(TS) indicates Top Secret
(S) indicates Secret
(U) indicates Unclassified
(C) indicates Confidential

Figure 3-1. Sample page markings.

storage of classified material. This is because of the risk that classified information may be compromised if it is stored with items that are often the target of thieves. A commander may waive this restriction in emergencies. A commander also may waive it temporarily when acceptable storage facilities are not available. However, the commander also must act to get the required storage facilities immediately.

Reproduction. Portions of documents and materials that contain Top Secret information shall not be reproduced without the consent of the originator or higher authority. The persons who are authorized to approve the reproduction of Top Secret and Secret information shall be designated by position title and shall review the need for reproduction of classified documents with a view toward minimizing reproduction.

The copying of classified documents shall be kept to a minimum. Specific reproduction equipment shall be designated for the reproduction of classified information. The rules for reproduction of classified information shall be posted on or near the designated equipment.

All copies of classified documents reproduced for any purpose, including those incorporated in a working paper, are subject to the same controls prescribed for the document from which the reproduction is made.

Destruction. There are six methods used to destroy classified matter: burning, melting or chemical decomposition, pulping, pulverizing, mutilating, and shredding.

Regardless of the method used, the destruction must be thorough. This is needed in order to preclude recognition or reconstruction of the information. There is a tendency to

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relax security on classified materials or information that has been marked for destruction. This should never be done, because the information may still be of high-intelligence value. When classified information is destroyed, the destruction must be certified. This is done by completion of a certificate of destruction, as outlined in DOD 5200.1-R and AFR 205-1. Security of classified information can never be relaxed — even when it about to be destroyed.

Suspected Compromise. Official information is assigned a classification because its unauthorized disclosure could be damaging to the national security. Therefore, when classified information is compromised or suspected of possible compromise, action must be taken to minimize the damage and to prevent repetition of the method of compromise. If you find that classified information is lost, or otherwise suspect that it has been compromised, you must notify your supervisor or commander immediately. On receiving such notification, commanders or their representatives must initiate action to protect the plans, operations, or projects affected. They do this by making the modifications possible and by initiating an inquiry to determine if a loss, suspected compromise, or compromise actually occurred. In such instances, commanders also must insure that an investigation is conducted to discover the compromise cause. This is done so that corrective and preventive action can be taken.

Exercises (015):

1. What does access mean?

2. What are the requirements for safeguarding classified information?

3. What must you have in order to reproduce classified information?

4. How may classified information be destroyed?

5. How do you account for classified information that has been destroyed?

6. What steps must you take in a case of compromise of classified information?

016. Name the required methods of transmitting classified information.

Transmitting or Transporting Classified Information. When you must transmit classified information or material from one point to another, you must follow these basic guidelines.

Top Secret. Top Secret information or material is moved by escort or courier, or is transmitted over electrical means (encrypted or cryptographic) that are protected from monitoring or intercept by enemy forces.

Secret. Secret information or material is moved by registered U.S. mail or the methods used for Top Secret materials.

Confidential. Confidential information or material is sent by certified or first-class mail, or by the means used for sending Secret and Top Secret materials.

Exercises (016);

1. How is Top Secret information transmitted?

2. How is Secret information transmitted?

3. How is Confidential information transmitted?

017. Briefly specify the purpose, controls, and importance of the industrial security program.

Industrial Security Program. To accomplish its mission as effectively and as economically as possible, the Air Force often enters into contracts with civilian agencies. Some of these agencies, or contractors, at times need classified information to do their job. Of course, when this happens the Air Force releases the needed information. This release does not lessen the sensitivity of the classified information involved or the need for its protection—far from it. The security that must be given classified information in the hands of a contractor is just as important as the protection we give it at our Air Force installations. For any compromise of classified information could seriously affect national defense. This is why the Department of Defense developed the industrial security program.

The industrial security program regulates the protection of classified Government information in the hands of industry. When the Air Force enters into a contract with a civilian contractor who needs classified information, a security agreement is drawn up as part of the contract. This is a formal agreement by the contractor to abide by the policies and procedures established by the Department of Defense for the protection of classified information. These policies and procedures are published in DOD 5220.22-M, *Industrial Security Manual for Safeguarding Classified Information,* and AFR 205-4, *Air Force Participation in the DOD Industrial Security Program.*

This program prescribes the uniform security practices that must be used in industrial plants, educational institutions, and all other facilities used by contractors who have access to, or possession of, classified Government information. Also, it applies to all aspects of contract activity,

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including preparation of bids and proposals, precontract negotiations, actual performance of the contract, and all postcontract activity.

Exercises (017):

1. What is the purpose of the industrial security program?

2. What controls are levied on a contractor possessing classified USAF information and materials?

3. Why is the industrial security program important?

3-2. Communications Security

Using the telephone to discuss classified information is strictly forbidden. So is using any other insecure method to discuss classified information. Discussion of classified information with insecure communications, however, is not the problem. The problem is that your unclassified telephone conversations with your friends and seemingly unrelated, unclassified telephone conversations made by other base personnel can provide an enemy agent with bits and pieces of information. Here, we examine communications security (COMSEC) and its importance to the protection of classified information. Our intent is to help you gain the knowledge you need in protecting classified information. Additionally, this text helps you satisfy some of the training needs identified in the communications security education program (CSEP).

018. Determine whether security precautions adhere to COMSEC guidelines in given situations.

Precautions. A very important part of our security program is communications security. It is designed to deny to unauthorized persons information of intelligence value which could be obtained by the possession and study of USAF telecommunications. Telecommunications are any transmission, emission, or reception of signs, signals, writing, images, sounds, or information of any nature by wire, radio, visual, or other electromagnetic system. Telecommunications also are sometimes referred to as electrical communications, or more simply, communications.

Need. Why do we need communications security? The answer is simple: to prevent unauthorized persons from intercepting our communications, studying them, and extracting any information of intelligence value. It is suspected that practically every major nation in the world today is making an effort to collect intelligence from the unclassified communications of the nations they oppose politically, economically, and militarily. They probably make this effort because unclassified communications, as we illustrate shortly, when collected and analyzed for intelligence content, can reveal details concerning an opponent's activities. For instance, operations, plans, programs, strengths, weaknesses, numbers, equipment, deployments, capabilities, intentions, and just about everything else can be obtained through communications monitoring.

Problem. The major problem facing the USAF today, with respect to communications security, is the fact that thousands of Air Force people must use unprotected communications systems to do their jobs. Very often, our jobs require involvement with classified activities or support of classified activities. Experience has shown that a study of numerous unclassified communications contacts, such as telephone calls about classified projects, can reveal certain details about those projects. Some examples follow.

Communication #1. The NCOIC of a fighter group operations office in the United States makes a telephone call to a distant supply activity. They inquire about the procedures for obtaining 100 copies of the air navigation maps for an area in the Middle East. The supply activity tells them to submit a form and that they will receive the maps within 3 weeks. The NCOIC says, "That will be fine," and hangs up.

Communication #2. An airman assigned to the engine maintenance activity of the same fighter group makes a telephone call the next day to a friend at a distant Air Force base. They tell them that they will be unable to take leave as originally planned, because all leaves have been canceled. The reason, they say, is that the workload is too heavy and will be for some time to come.

Communication #3. A medical officer assigned to the same fighter group calls a fellow doctor at Wilford Hall Medical Center in San Antonio, Texas. After mentioning that they recall that their friend had, years ago, been stationed at Dhahran Air Base, Saudi Arabia, they ask them about certain diseases which are common to that area, and for a list of reference books on these diseases. Their friend is surprised at their interest in these things, and asks, "How come?" The medical officer replies that she might be able to use the information sometime.

Communication #4. A Security Police officer assigned to the fighter wing, using their base telephone, calls another Security Police officer during the night. During the conversation, the first Security Police officer remarks that it is very dull and quiet around here. The other Security Police officer states, "In about a month you won't be making that complaint—you could find things quite exciting."

Communication #5. A staff officer of the fighter wing makes a radio telephone call to Japan to contact Colonel Smith, the wing operations officer. (This call, made from his desk, is connected to radio equipment on his base that beams the call, via high-frequency radio energy, to a base in Japan. At that point, another connection to normal telephone circuitry completes the radio telephone connection.) The staff officer has considerable difficulty finding Colonel Smith. In the process of reaching him, he has to explain that Colonel Smith is the 82nd Fighter Wing Operations Officer, currently TDY to the Pacific, and is visiting Colonel Jones, Director of Intelligence. When the staff officer finally reaches Colonel Smith, he tells him that the Wing Commander wants him to cut his TDY short and to get back home quickly. When Colonel Smith asks why, the staff officer says, "Something big has come up, we are plenty

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busy, and I can't say much more than that you are needed and quickly."

Commentary. Each of the fictitious communications above is unclassified. No one violated security. In each example, the people communicating had no idea that the other conversations had taken place. And yet, we can see from examining all of the conversations together that each call contains bits and pieces of story—a story that to enemy intelligence analysts would probably be reported to their superiors along the following lines:

> From communications intelligence intercept of the 82nd Fighter Wing telephone and point-to-point communications, it appears probable that this wing has been alerted for deployment to the Middle East area within the next 30 to 45 days. Intercept activities continuing. Further details will be reported as developed.

Far fetched? Not at all. Air Force security service communications security surveillance teams, who monitor USAF communications facilities from time to time, have proven conclusively that it is possible to develop such information if you are able to get access to these communications.

Access to our communications is a simple matter if one has the proper equipment. Telephone calls, for example, can be tapped in so many ways that the people using the telephone cannot detect the presence of a tap. The conversations can be recorded and studied later by an intelligence analyst.

Automatic voice network (AUTOVON) calls are even easier to intercept, because these long-distance calls are usually transmitted by radio beams between towers about 25 miles apart. Anyone with the proper receiver can intercept them. Radio communications are even simpler to intercept. The interceptors need only the right receiver, and to be in a location where they can receive the radio signal.

Exercises (018):

Homestead AFB is the headquarters for a Top Secret unit deployment. The classified code word for the project is "SKYWAY." The unclassified code word is "Blue Knight." In each of the situations below, determine if proper COMSEC measures have been used. If incorrect procedures are used, state what the correct procedures are.

1. Sgt Jones, NCOIC of the deployment, picks up the office phone and calls Hickam AFB by AUTOVON. Sgt Jones asks Sgt Smith, in Hawaii, if the rosters for Blue Knight are ready and when they will be sent to him. Sgt Smith is not familiar with Blue Knight, so Sgt Jones tells her it concerns having a bunch of people ready to move very soon.

2. Maj Johnson, project officer for the deployment at Homestead AFB, sends an encrypted classified message to all bases involved in project SKYWAY, requesting that each base alert 100 men and women for deployment to an unknown location within 6 hours.

3. Sgt Brown is in a hurry to get some information concerning SKYWAY. She calls Randolph AFB and asks that the information listed in Maj Johnson's request of 2 days ago be sent to her by encrypted message within 1 hour.

4. Sgt Adams sends a routine message to all bases involved in SKYWAY which reads in part: "All Blue Knight actions are delayed 1 day, i.e., exactly 24 hours."

019. List the elements of communications security, state their purposes, and indicate which elements apply throughout the Air Force.

Elements of COMSEC. Communications security consists of four elements—transmission security (TRANSEC), cryptosecurity, emission security, and physical security. Although each area is considered an element of COMSEC, the first three elements listed apply to our various telecommunications modes. The fourth element, physical security, relates to the actions needed and taken to protect our COMSEC equipment, materials, and information.

TRANSEC. This means taking protective measures to insure that our communications are not intercepted and exploited by enemy forces. It is important that you understand this component of COMSEC, since you must protect any sensitive information that you are entrusted with or come in contact with during your daily duties. The biggest problem created in TRANSEC is the administrative telephone. This is because the telephone is our most frequently used mode of insecure communications. However, you need to use TRANSEC every time you use an insecure communications medium; for example, the AUTOVON telephone system, the portable two-way radios in our vehicles, or the VHF air-ground radio systems in our aircraft. Some of the measures you can take to insure good TRANSEC are:

a. Planning your telephone conversations in order to avoid topics of intelligence value.

b. Limiting discussion of classified information in a work center/duty section while the telephone is being used.

c. Cautioning persons using a telephone if their conversation appears to border on classified or sensitive areas.

d. Transmitting classified information by appropriate mail, courier, or cryptographically secure methods.

e. Eliminating from your work center/duty section the use of homemade codes, self-made reference systems, brevity lists, and attempts to "talk around."

"Talking around" a classified subject is trying to disguise the real meaning of your conversation. This is done by using vague terms and relating them to items known to you and the person you are talking to, without actually using classified terminology. Self-made reference system may take many forms. For instance, using the second letters of words to make up other words, or adding and subtracting digits from your social security number in order to pass along a classified number. Brevity lists do not provide security. They are used only to shorten messages. The well-known 10 series

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codes used in many two-way radio transmissions are an excellent example of a brevity list. Attempts to use any of these unauthorized methods of passing classified information are easily recognized and understood by trained intelligence analysts.

To help counter these TRANSEC deviations and help plug intelligence leaks, a program known as essential elements of friendly information (EEFIs) is used throughout the Department of Defense. This long phrase describes the types or categories of information that, if known by an enemy, could jeopardize the success of a USAF operation. In the Air Force EEFIs are included in TRANSEC. EEFIs are nothing more than listings of sensitive information that should be protected. Air Force regulations require each major command (or separate operating agency) to publish a general listing of EEFIs that apply to the command's overall mission. EEFIs are most effective, however, when prepared by supervisors and tailored for use in individual work centers/duty sections. Figure 3-2 illustrates the type of information considered essential elements of friendly information. You can use EEFIs as a guide to help prevent disclosure of information about your job, your unit, your base, etc. Similar EEFIs also are used by COMSEC support units as criteria to evaluate the communications security posture of friendly forces.

Cryptosecurity. This is the component of COMSEC that results from applying technically sound cryptosystems and their proper use to our communications. In other words, modern electrical means are used to encode, scramble, and otherwise mix up (encrypt) information. This is done so that an enemy intelligence force cannot decipher the meaning of the information when the information is transmitted from one point to another.

Emission security. This part of COMSEC results from all the measures we take to deny unauthorized persons information of value. In particular, this element deals with reducing enemy attempts at intercepting and analyzing information coming from (emanating) cryptographic and telecom-

* The introduction of new equipment.

* The security clearances of individuals.

* Information on the itineraries of important official visitors and the purpose of their visits.

* Medical immunization requirements or actions that indicate possible operational intent or activity.

* Map or mapping requirements that indicate operational planning activities or possible operational intent.

* Nicknames, short titles, and security classification of any classified operation, project, or activity.

* Equipment or personnel shortages and deficiencies that impair the operating efficiency or combat readiness of units or forces.

* The status of tactical training, combat readiness, or combat efficiency of units and forces.

* Information on the identity, location, movement, or changes in the strength of units or forces.

* Changes in:

  a. Command relationships and general or specific information relating to unit or force organization.

  b. Unit or force mission.

  c. Organization.

  d. Equipment that alters unit or force operating capabilities.

Figure 3-2. Data considered essential elements of friendly information.

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munications. Emission security is often confused with emanations security (EMSEC). EMSEC is not a part of COMSEC. EMSEC deals with information produced from (emanated) sources other than cryptographic and telecommunications; for example, electric typewriters.

Physical security. In this instance, the term "physical security" applies to the physical security of COMSEC equipment, material, and information. Actually, this COMSEC element is an adaptation of two separate security programs—information security and physical security. The physical security element of COMSEC simply means using physical measures to prevent unauthorized people from gaining access to COMSEC equipment, material, and documents. Normally, you will not be concerned with this aspect of communications security unless you work in an area where cryptographic material is used. If this is the case, additional guidance would be provided by your local COMSEC custodian.

Interrelation. Summing up, COMSEC is nothing more than the protection that results from all the measures you take to deny unauthorized persons access to information of value. Specifically, COMSEC relates to measures used to guard against an enemy studying information gathered by monitoring our communications. Everyone in the Air Force must know how to apply these measures, particularly those common to transmission security. The use of cryptosecurity, emission security, and physical security of COMSEC equipment, materials, and information normally applies only to persons in certain USAF duty positions. However, because of your duty assignments, you may become involved in these COMSEC areas; remember them.

Exercises (019):

1. What four security actions make up the COMSEC program?

2. What purpose is served by each of these four security actions?

3. Which COMSEC element is most applicable to everyone in the Air Force?

4. Based on your answer to exercise 3, why is this the most applicable?

5. Based on your answer to exercises 3 and 4, what action can a supervisor take to reduce intelligence leaks common in this area?

020. Identify the common violations that may occur while using the telephone.

Telephone Off the Hook. Do not discuss classified or unclassified information of intelligence value, or permit it to be discussed in the vicinity of a telephone which is off the hook. Conversations near an in-use telephone can be picked up and transmitted about as readily as the conversation of the person talking into the telephone.

Unplanned Conversations. The greatest problem of the telephone system is the people who use it. For example, during a telephone conversation, have you ever said, "Oh, by the way"? These words usually precede a bit of information you did not intend to discuss when you first picked up the telephone. This practice of not planning telephone conversations frequently leads from discussing unclassified information of no intelligence value to discussing information of intelligence value, *and, at times, even further.*

Attempting to Disguise Information. Some people who try to fool anyone who might be listening in on a telephone conversation may do so by attempting to disguise or conceal the meaning of what they are saying. Some of these attempts are cleverly developed and some are very crude but none are successful. This practice is commonly known as talking around. There are two methods of talking around commonly used. These are paraphrasing and comparing with similar subjects. An example of paraphrasing is: "I cannot tell you who the VIP is, but this person is the Vice President's boss." Even though it may sound like a riddle, it is a bit of paraphrasing that was used in an actual conversation. In this example, the wording was changed without changing the meaning. Who is the Vice President's boss? This person is, of course, the President. You can see that paraphrasing is changing the wording without changing the meaning of a subject. An example of comparing with similar subjects is: "Next year we are going to be flying the same model that you have at Lackland AFB." You may think that this statement is paraphrasing; however, notice the added attempt at deception: comparing with similar subjects. If you know what type of aircraft they have at any air base, the information is not successfully concealed or disguised.

Homemade Codes or Ciphers. Another disguise that many people make in an attempt to conceal the meaning of information of intelligence value is their own code. These homemade codes or reference systems are never effective and should never be used in place of authorized codes, ciphers, or secure communications systems. It is easy for an experienced cryptanalyst to decipher any homemade code system.

Remember, the "third man" is listening. He represents an enemy engaged in obtaining intelligence information from USAF electrical communications.

Exercises (020):

1. What are the most predominant security violations associated with the use of the telephone?

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2. What form of security error is committed by the telephone user who offhandedly interjects additional thoughts about a classified project into the telphone conversation?

3. In what manner do people try to talk around classified information?

3-3. Operational Security

From the previous text, you already know that classified information must be safeguarded by every means available. Also, you learned specific facts concerning the security of communications systems used by the Air Force. Undoubtedly you can recall the series of unclassified conversations that were used as an illustration. These programs, however, do not fully satisfy our needs for protecting USAF information.

All information about an Air Force operation also needs protection because such information is valuable to our enemies. This protection is provided under the Air Force Operational Security (OPSEC) program. OPSEC is an overall security program relating to mission accomplishment. It is concerned with the information, actions, and activities that are sensitive in the sense that they can telegraph our punch to the enemy—they can give advance warning.

In this section, we discuss the Air Force OPSEC program. It is applicable to all peacetime and wartime missions whether operational or supporting. Every Air Force member has a responsibility to maintain operational effectiveness at the highest possible level. This responsibility includes an obligation to apply OPSEC principles and procedures in promoting overall security without detracting from operational effectiveness. You need to know this information to fulfill your OPSEC responsibilities.

021. Briefly define the historical aspect of operations security and state the purpose of the OPSEC program.

OPSEC History. The success or failure of most major combat operations depends on the element of surprise. Before an operation can be started, people must be assembled, equipment and transportation massed, and numerous other activities completed. However, when preparing for an operation, we usually show definite patterns of behavior or action. These patterns can become warning signs to enemy intelligence collectors. They can show that an operation is underway or being planned. Attempts to gain information about planned operations is not new; it is an age-old practice. The activities of opposing forces are constantly monitored to obtain signs of planned operations. This is done because such forewarning may provide time to take countermeasures that reduce or eliminate any advantage that may have been created by surprise. In view of this, it is easy to see the need for assuring that sensitive information about our combat operations is controlled.

On the other hand, the need for controlling sensitive information is not as obvious if the information does not seem to be related to a combat operation. Consequently, several Air Force studies were made to find out how sensitive information was being compiled by enemy intelligence sections. For the most part, these studies revealed that sensitive information about combat operations could be obtained, without anyone violating any security rules, by using nothing other than commonsense. For example, in Viet Nam, Security Police flight duty schedules and rosters were being posted in locations where foreign nationals could screen them. This was being done as much as 24 hours prior to the scheduled worktime. Moreover, these studies showed that just before a major air strike against Viet Cong targets we increased our security readiness postures and exercised more strict base entry procedures for foreign nationals.

How many security rules did this violate? None. Could these actions provide a trained enemy espionage agent with enough sensitive information to piece together a picture? By themselves, maybe not. But when combined with overheard comments like "We must be getting ready to hit Hanoi; they loaded 500 pounders (bombs) on every plane this afternoon," the picture begins to come into focus.

Under these conditions, the need for an Air Force-wide program to control and protect sensitive information became more and more visible. As a result, the OPSEC program came into being.

Purpose. OPSEC is concerned with keeping the tactical and strategic surprise on our side, by protecting information and activities affecting this principle. We must protect knowledge of our plans, resources, and limitations. The proper protection of classified information and material is part of OPSEC; so is the protection of seemingly trivial or insignificant unclassified information and actions which are related. In other words, we must protect information or actions that are sensitive. A simplified statement about the purpose of OPSEC is "to keep the advantage on our side." The successful completion of our mission and the use of OPSEC is greatly dependent on each individual recognizing what information and actions need protection. However, there is a point of diminishing returns in applying OPSEC. This point is reached when our overall security measures detract from operational effectiveness. There must be a balance between security mission accomplishment.

Exercises (021):

1. How has history shown the need for an OPSEC program?

2. What is the purpose of OPSEC?

022. List the objectives of the OPSEC program and state the resources and types of information that could forewarn an enemy.

OPSEC Objectives. The OPSEC program is conducted on a full-time basis, as are Air Force programs for informa-

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tion and communications security. OPSEC also is similar to these programs in key elements, such as individual responsibility and need-to-know. Specifically, our OPSEC program has four major objectives:

(1) Identify those portions of an operation that require protection.

(2) Develop OPSEC procedures and techniques.

(3) Systematically assess OPSEC status at all operational levels.

(4) Document deficiencies and institute corrective actions.

Sources and Types of Information. There are many sources or possible sources of information that give the enemy advance warning. Generally, these can be placed in one of three categories that are common to any military activity: operations, procedures, and communications. Figure 3-3 presents typical intelligence indicators under each of these categories. Within each of the categories there are numerous items of sensitive information. Examples of the types of information that need protection are:

- Objectives of the operation.
- Operation times and locations.
- Friendly and enemy forces involved.
- Known or suspected limitations.
- Methods of employment.
- Results of the operation.
- Sources of intelligence data.
- Methods of data collecting.

Exercises (022):

1. What are the objectives of the OPSEC program?

2. What are the sources of information sought by the enemy?

3. What types of information does the enemy use to gain advance warning?

023. Given hypothetical situations, determine whether OPSEC objectives and purposes have been met.

Lessons Learned. The main objective of OPSEC is to provide protection for our operations during the planning, execution, and after-action phases. Any actions that could affect the successful completion of an operation, or the protection of the mission, fall under OPSEC. One of the most important lessons we have learned about ourselves is the ease with which an enemy can obtain advance knowledge of our operations. We also learned that closely related to this was the apparent lack of importance attached to comments such as we used earlier in this section. Air Force studies of this area also showed that changes to our normal routines contributed to security weaknesses. Finally, and perhaps most startling, was the fact that the Air Force concern for its people was a major factor in creating security weaknesses. This was the result of getting the word out to everyone concerned, thus creating such a grapevine that in some instances dependents on a base had almost as much knowledge about the what, when, where, why, and how of an operation as the person in charge.

On that account, we now know that you, the individual at the working level should be aware of the intelligence impact your information and activity has in relation to the overall security of an operation. Therefore, to do our job under OPSEC, we must:

- Change only those procedures or actions that need to be changed.
- Learn to work with those procedures that are needed and cannot be changed.

The need for OPSEC is quite easy to see in combat operations. However, what of peacetime operation and projects? To answer a question with a question, "Why make the opportunity available?" For instance, recall, if you will the types of operational information that should be protected. Generally, the subjects such as objective, time and location, forces, limitations, methods of employment, and data collection, results, and intelligence sources should come to mind. The key point to communicating these subjects is *do not* unless the person you are talking to has a need to know and a secure method of communication is used. This applies equally to combat operations and our peacetime operations.

Exercises (023):

In each of the following situations, you are stationed at a Northern U.S. strategic missile base and you are assigned the job of determining if the base OPSEC purposes and objectives are being met. Your survey results in the following information. Now you must decide whether the OPSEC purposes and objectives were met in each situation. Explain your answer.

____ 1. The wife of the wing commander appears on the local TV talk show and discusses the importance and benefits of Air Force and local community relations.

____ 2. Sitting at the base cafeteria, you overhear two enlisted missile crewmembers talk about a problem they had repairing a malfunctioning launch hoist at Juliet site.

____ 3. On sick call you overhear several dependent wives discussing the distances from their homes to Fox, George, and Romeo sites.

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OPERATIONS

* Stereotyped sequences of events comprising various phases of the operations.

* Coordination with other agencies that do not have proper safeguards for classification/sensitive information.

* Stereotyped patterns of flight activity (ingress and egress) at a particular location and time.

* Submission of unclassified reports at specific intervals to specific units or levels of command.

PROCEDURAL

* Public Information releases.

* The posting or transmission of operations orders, flight plans, air traffic control clearances, etc., in unsecure areas.

* The posting in unsecure areas of duty rosters, transportation schedules, dining hall schedules, etc., which change as a result of an operation order.

* Distinctive emblems or paintings on vehicles, buildings, or aircraft.

* Markings on supplies which could reveal the location or starting date of the operations; that is, nicknames, delivery deadlines, etc.

* Logistic buildup or positioning of support materials and facilities.

* Specific briefings, meetings, or religious services.

* The use of nicknames is a particular hazard since a nickname provides an easily recognizable "flag" for numerous actions associated with a particular operation.

* Exercising the plan or testing portions of the plan.

COMMUNICATIONS

* Plain language communications associated with a planned operation and conducted during the planning, preparatory, and execution phases.

* Use of unchanging or infrequently changing call signs or radio frequencies.

* Stereotyped message characteristics (voice or teletype) which are indicative of particular types of military activity.

* Significant increase or decrease in message traffic volume.

* Activities of new communications facilities in support of an OPLAN.

Figure 3-3. Intelligence indicators.

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____ 4. Your base newspaper has a large front page story of how missile launch crews from your base won the first place award at the last missile competition at Vandenberg AFB.

____ 5. At the base library you find a copy of a recent IG inspection report and some portions of it are marked "(S)."

____ 6. You learn that base reproduction is printing TDY orders for 50 missile crew personnel to attend a school at a classified location in order to learn about a revised missile launch system.

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CHAPTER 4

Publications

AS AN AUTOMATIC tracking radar repairman, you may often feel that your work with Air Force publications and maintenance management forms and procedures is of little importance. However, the accuracy and currency of forms are very important to the Air Force. Every radar repairman should know the current procedures to be followed in performing and documenting maintenance actions.

4-1. Air Force Publications

Have you ever started to do a job without any idea of how to do it, where to start, or what you need to complete it? This is where Air Force publications come in. They save you time and energy. Why should you stumble and fumble making up procedures that others have already worked out?

There are many types of Air Force publications. It is to your advantage to learn about these publications and how to use them. As a radar repairman, you will use technical order publications more often than you use standard publications (regulations and manuals).

Even so, you should become acquainted with the various types of Air Force publications. You should also become adept in the use of indexes and other basic references. This will help you to locate the information that you need to perform the tasks in your work. In this chapter we shall first examine the types of Air Force standard publications. Then we will proceed toward your more immediate concern, a survey of the Air Force technical order system.

024. Identify the general classes and subclasses of publications.

Classes of Publications. Air Force publications are divided into two general classes: departmental and field. Departmental publications are issued by (or for) HQ USAF. They apply to the entire Department of the Air Force. Field publications are issued at major command level or below for use within the issuing organization. These two general classes are further divided into standard publications and specialized, miscellaneous, and other publications.

We will begin our discussion with standard departmental publications. They are used to announce policies, assign responsibilities, prescribe procedures, direct actions, and inform or motivate personnel. Let's look at standard publications and their specific uses.

Air Force regulations (AFRs). Regulations contain directive and policy material and assign responsibilities. They may include brief procedure details when necessary. Regulations are usually permanent in nature. When it is known that a regulation will cease on a specific date, the expiration date is included. Air Force regulations are the most numerous of all Air Force standard publications.

Air Force manuals (AFMs). Manuals are used in the same manner as regulations. They are often identical in appearance, volume, scope, and applicability. Because there are no unique characteristics which distinguish manuals from regulations, manuals will be phased out as they are scheduled for revision and will be republished as regulations.

Air Force pamphlets (AFPs). Pamphlets usually contain information of a nondirective nature. They are written in an informal style and are usually published in brochure or booklet form., They are permanent, but an expiration clause may be included if it is desired.

Operating instructions. Operating instructions are similar to regulations but apply only within the issuing headquarters. These instructions are designated "headquarters operating instructions" (HOIs), "branch operating instructions" (BOIs), etc. OIs must comply with existing higher level directives and be updated accordingly.

Visual aids. Visual aids are charts, posters, or graphic illustrations issued for display on walls, bulletin boards, or other suitable places. They are either temporary or permanent in nature. Temporary visual aids are not numbered and have an expiration date printed on the bottom. Permanent visual aids are numbered and indexed in the same manner as other publications.

Bulletins. Bulletins contain announcements, notices, and temporary instructions. For example, daily or weekly bulletins fall into this category.

Staff digests. These contain summaries of significant staff actions, important announcements, and special notices. They are issued periodically or when needed, and at various command levels.

Supplements. Supplements are used by lower headquarters to implement, amplify, interpret, or clarify a higher level publication. A supplement does not alter or change the intent of the basic publication. Supplements are filed behind the basic publication or behind the supplement of the next higher headquarters.

Exercises (024):

1. The Air Force issues both standard and specialized publications. Which of these will normally be used to

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announce policies, assign responsibilities, prescribe procedures, and direct action?

2. Identify the Air Force publication that is written in an informal style.

3. Indicate the regulations that apply only within the issuing organization.

4. In what order and in what location are supplements filed in publication binders?

025. Identify the basic subject, the numbers used in the Air Force publication system, and the governing sources.

Basic Numbering System. Because of the large number of Air Force publications, a method for identifying them quickly is needed. The Air Force has developed subject and numbering systems to do this. Basic subjects and basic numbers are assigned to publications from the list in AFR 5-4, *Numbering Publications.*

Regulations, manuals, and pamphlets have a double-number system to simplify reference and control. For example, consider AFR 35-3, *Service Dates and Dates of Ranks.* The first number, 35, is the basic number. It shows the basic subject of the directive to be military personnel. The second number, preceded by a dash (-3), indicates exactly what area of military personnel is covered. In this case, the specific title corresponding to the second number, -3, is Service Dates. The numbers are assigned by the Director of Administrative Services HQ USAF. They identify the publication and, with the title, help you locate the exact information required. It is simpler to refer to a publication by its specific title than by its subject matter.

The basic number is the same for related subjects throughout the different types of publications. For example, AFR 34-3, AFM 34-4, and AFP 34-1-9 all are in the personnel services area. So each has the same basic number of 34. The second number of the AFR, AFM, and AFP tells what part of the Personnel Services each area covers. Note in the above example that the pamphlet has an additional or third number. The first number is the basic number, the second number provides for grouping under secondary subjects, and the third number is for a more detailed breakdown. This permits closely related subjects to be issued in separate pamphlets with the same basic and secondary numbers.

Supplements are identified with the basic publications which they supplement and are numbered in sequence; for example, ATC Supplement 1 to AFR 4-1, *Functions and Responsibilities of Administration.* Remember that every Air Force publication is given a number and title. This makes it possible to index and file all publications in an orderly fashion. This makes it simple for you to locate any publication quickly and easily.

Exercises (025):

1. AFR 5-4 contains a list of basic subjects that is important to us. What is the title of this list?

2. Air Force regulations, manuals, and pamphlets normally begin with a double number (34, 35, etc.). What do these numbers indicate and how are they used?

3. Which of the three groups of numbers below indicates an Air Force pamphlet?
   a. 34-3.
   b. 3-43.
   c. 34-1-9.

026. Describe the correct procedures we must use in order to maintain technical orders and other publication files current.

Index-type technical orders give us a means of selecting needed TOs. In certain instances, they group the technical orders pertinent to specific items of equipment. Also, you can tell the status of technical orders in the file. Now let's briefly look at some types of indexes.

Air Force Technical Order System. The automatic tracking radar specialist who maintains Air Force equipment must know how to use Air Force technical orders (TOs). The Air Force TO system was established as the official method of disseminating technical data, instructions, and safety procedures pertaining to the operation, installation, maintenance, and modification of Air Force systems. Technical publications are published and distributed by the Air Force Logistics Command (AFLC). Publications printed by other Department of Defense agencies for equipment are incorporated into the Air Force TO system. These may be printed and bound according to the specifications of the procuring agency. Numbers are assigned to them before they are listed in the pertinent technical order index. The Air Force TO system is authorized by and explained in AFR 8-2, *Air Force Technical Order System;* however, detailed explanation of the system is covered in the 00-5 series of technical orders.

Technical order indexes (TO indexes). TO indexes are listings of TOs within categories (groups) of equipment. These indexes include the necessary information for ordering the TOs. This index group begins with the index of indexes (TO 0-1-01) in which all the indexes are listed numerically. Actually the TO index is composed of publications applicable to a *specific* category of equipment. Some examples follow:

a. Category 0, Indexes.
b. Category 00, General Technical Orders.

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c. Categories 2 through 16, Aircraft and Missile Equipment.

d. Categories 31 through 50, Ground Equipment.

Along with the numerical listings, you can find the TO issue date, change date (if any), and security classification (if any); you can also check the availability. Standard symbols are used to indicate which publications are in the particular file.

These symbols are placed on the AFTO Forms 110, Technical Order Distribution Record.

The Alphabetical Index, TO 0-2-1, is an easy method for locating the correct TO number group when the type of equipment is known. This TO does not give you the status but refers you to the proper TO index category. The list of applicable technical orders (LATO) provides listings of all TOs applicable to a specific weapon or system. It helps determine the contents of limited TO files which may need to be established. Proper use of these indexes will enable you to locate other TOs needed to perform your duty.

Filing sequence. TOs cover a large number of subjects. A good numbering and filing system is needed so that repairmen can quickly locate information they need. Let's discuss the numbering of technical orders first.

As mentioned, detailed explanation of the TO system is covered in the 00-5 series of TOs. It is further outlined in 00-5-18.

In our present numbering system, each TO number is divided into three or more parts, each separated by a dash (-). As an example of this system, the numbering of TO 31P2-2MSQ77-4 is used in figure 4-1.

The first part usually consists of three designators, numerical and alphabetical. The first designator is the number 31 and identifies the TO category, which in this case is Ground Electronic Equipment. The second designator is alphabetical and identifies a major group of publications. In the example shown in figure 4-1 the second designator is P, which identifies Radar Electronic Equipment publications. If this designator had been M, it would be Meterological Equipment publications. The third designator is numerical and identifies a major subgroup of publications. When used in Radar Electronic Equipment publications, the designator has the following meaning.

1—Auxiliary (example, 31P1-2GPA5 series).
2—Control (example, 31P2-2MSQ1 series).
3—Height Finding (example, 31P3-2FPS6 series).
4—IFF (example, 31P4-2GPX9 series).
5—Navigation (example, 31P5-2MPN13 series).

The first digit in the second part identifies the type of equipment nomenclature as follows:

-1—General (publications pertaining to the equipment category designated by the first part of the TO number).
-2—AN nomenclature.
-3—Signal corp nomenclature.
-4—Commercial nomenclature.
-5—AF nomenclature.

The third and final part of the TO number reflects the type of publication as follows:

Operating instructions: -1, -11, -21 through -491.

Service or maintenance instructions: -2, -12, -22 through -492.

Overhaul instructions and/or circuit diagrams: -3, -13, -33 through -493.

Parts catalog: -4, -14, -44 through -494.

Planning data and/or installation instructions: -5, -15, -55 through -495.

Preventive maintenance instructions: -6, -16, -66 through -496.

Standard installation instructions: -7, -17, -77 through -497.

Inspection and testing procedures: -8, -18, -88 through -498.

Alignment procedures: -9, -19, -99 through -499.

E&I standards: -10, -20, -30, etc.

Time compliance technical orders: -501 through -1000, then -1500 through -2000.

In the example in figure 4-1, the TO numbers can now be completely identified as the parts catalog for Ground Radar Control Equipment type AN/SQ-77.

The TOs in your shop will be filed in a numerical, alpha-

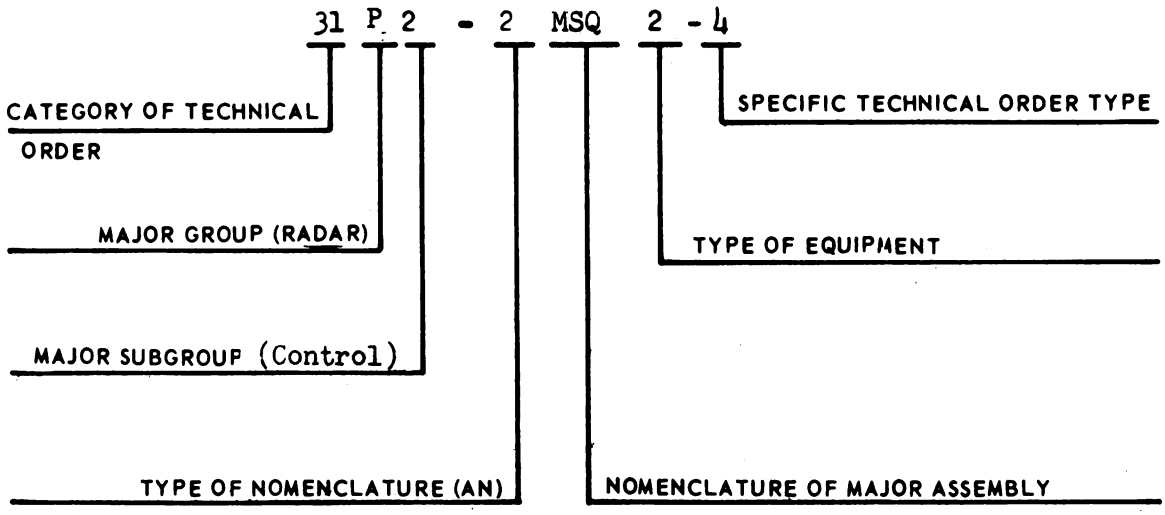
31 P 2 - 2 MSQ 2 - 4
CATEGORY OF TECHNICAL ORDER
MAJOR GROUP (RADAR)
MAJOR SUBGROUP (Control)
TYPE OF NOMENCLATURE (AN)
NOMENCLATURE OF MAJOR ASSEMBLY
TYPE OF EQUIPMENT
SPECIFIC TECHNICAL ORDER TYPE

Figure 4-1. Breakdown of technical order numbering system.

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betical order. For example, TO 31P4-2GPX9 series, would be filed after TO 31P2-2MSQ77 series.

Changes, revisions, and supplements. It is the Air Force objective to insure that related or interfacing technical orders are compatible at all times. This is done by the use of changes, revisions, supplements, and appendices.

Changes are issued when only parts of the existing TOs are affected. The changed pages replace the corresponding numbered pages and all replaced pages must be removed from the TO. The list of effected pages will be on the reverse side of the new title page. Under the column headed "change number," the number of the change is listed, such as 1, 2, 3, etc. The 0 is used to denote original issue of a page, a blank page, or a group of original pages. A word of caution before filing, the complete change should be checked against the new listing to insure completeness and accuracy. The basic date on the cover page of the change should match the basic date of the cover page being replaced.

Supplements are issued to augment or to change data in the basic TOs. This material is not adaptable for inclusion as individual change pages. Safety and operational supplements will be filed in front of the basic TOs. If you have an operational and a safety supplement for an individual TO, the safety supplement must be filed in front. Other supplements on the basic title page. Revisions are used to replace an existing TO. Normally the title page of the revision will have a statement, such as "This Publication Supersedes TO (TO number and date)."

Before filing, the replacement "note," TO number, and title page should be checked against the title page of the TO being replaced. If no discrepancy exists, the old TO is removed from the file and the new TO put in its place.

Exercises (026):

1. Which Air Force regulation authorizes the Air Force TO system?

2. Which publication would you refer to for the necessary information for ordering TOs?

3. If you are assigned the responsibility of maintaining the TO file in your section, where could you find a detailed explanation of the TO system?

4. Where can you find a list of TOs applicable to a specific weapon or system?

5. In TO number 31P2-2MSQ77-4, what does the 31P2 indicate?

6. TO 31P2-2MSQ77-9 is what type of technical order?

7. Where in the TO should safety supplements be filed?

8. What precaution should you take before posting a TO change?

027. Given a typical hypothetical situation, identify the TOs necessary to solve the problem.

Categories of TOs. As you know, the automatic tracking radar field encompasses many varied and highly complex types of equipment. It would be virtually impossible for one to remember all the information necessary to maintain the equipment you may come in contact with in this career field. Learning to use the different categories of TOs properly will save you many hours. We will discuss separately the TOs that you will use the most in the performance of your duties.

Technical Manuals (TMs). The technical manuals contain the operation and maintenance instructions designed to meet the needs of personnel engaged or being trained in the operation, maintenance, service, overhaul, installation, and inspection of specific items of equipment and materials. TMs covering specific ground electronic equipment are published in separate manuals which are discussed in the following paragraphs.

Service manual. This manual covers all the information necessary for the installation, operation, maintenance, calibration, and repair of the equipment concerned. The following list identifies the five chapters that you will find in a service manual.

Chapter 1—General Information. This chapter gives description and purpose, leading particulars, and the equipment supplied with the system. Some examples are: Beam width, power requirements, range, transportability, tools and/or test equipment supplied, etc.

Chapter 2—Installation. This chapter provides information on installation, planning, and logistics. Some examples are: Hardstand requirements, site accessibility, power availability, etc.

Chapter 3—Operation. This chapter provides brief information on controls, indicators normal and emergency operating instructions.

Chapter 4—Principles of operation. This chapter covers functional system operation and functional operation of electronic circuits.

Chapter 5—Maintenance. This chapter describes the maintenance performed in the field and at depot.

The technical information in this manual is written from the standpoint of a maintenance person with previous experience with related equipment. All basic theory is excluded from the explanation. Should basic theory be required, you should consult TO 31-1-141 series.

Circuits and diagrams. This TM contains all circuits and diagrams, waveforms, and voltage-resistance charts for a

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specific type of equipment. This TM will be used extensively in troubleshooting radar equipment.

Illustrated parts breakdown. This manual contains a group assembly parts list and a numerical index of the articles, assemblies, and subassemblies that can be assembled, reassembled, or replaced. It should list these items by the manufacturer's part number and, in some cases, the stock number. The illustrated parts breakdown will provide you the information required for ordering parts.

Preventive maintenance workcards. These workcards are a set of simplified instructions, presented in a step-by-step fashion. They consist of performance routines and servicing routines, such as cleaning, oiling, and greasing of components. These workcards identify the tools necessary to complete the routine and the time required.

Alignment manual. This manual contains the information necessary for complete alignment and adjustment of the equipment. It does not include specialized maintenance or factory level alignment procedures, primarily because these are not usually performed by field personnel. These instructions are written to be readily understandable by 5-level maintenance personnel. It is assumed that the maintenance personnel are familiar with the operation of the test equipment allotted for the maintenance of the equipment.

Time compliance technical orders (TCTOs). TCTOs set forth instructions for modifying equipment, performing, or initially establishing special inspections. TCTOs will be covered in more detail later.

Exercises (027):

1. If you are called upon to assist in the installation of a new system, what technical manual would you need?

2. You recently received a call from Job Control concerning an indicator problem. A close visual inspection reveals in-depth troubleshooting will be required. List the TMs you will probably need to repair and return this indicator to operational status.

3. While inspecting some radar equipment, you find some components that should be replaced. Which TM will provide the information needed to order replacement parts?

028. Describe the purpose of a technical order improvement report.

Technical Order Deficiency Reporting. The term "deficiency" denotes an error or defect which changes the meaning of instructions. It could also give insufficient information to adequately perform a task or function. (Example: misspelled words, typographical errors, and improper sequencing of pages.) An AFTO Form 22, Technical Order System Publication Improvement Report and Reply, is initiated by the person who discovers the deficiency. His or her supervisor checks that the deficiency is valid and important enough for submission. The deficiency report next goes to Quality Control for approval. Then it goes to the Air Force Logistics Command (AFLC) depot indicated in the storage and issue column of TO indexes. AFTO Forms 22 are submitted in one of three priorities—Emergency, Cover Letter, or Routine. Before you submit the report, consult with Quality Control. They will advise and assist you.

AFLC takes action on emergency reports within 48 hours after receipt. On cover letter reports, action is taken within 40 days. Unless routine reports are disapproved, AFLC makes no reply to them. Changes to TOs are published within 240 days.

Each of us has the responsibility for reporting any TO deficiency to insure that we have the best up-to-date TOs possible. Further information can be found in TO 00-5-1.

Exercises (028):

1. While using a technical order, you find what you believe is an error because step 13 required external power to be disconnected. Step 14 requires a test set to be connected, step 15 directs application of external power, step 16 directs pulling circuit breakers A7, A9, and A10 because equipment damage will result if power is applied and steps 17 through 19 could not be completed satisfactorily. Should you submit a deficiency report on this type of error?

2. Identify the major command that processes deficiency reports that are submitted.

3. Identify the maintenance branch that will assist you in submitting deficiency reports.

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CEM Maintenance Management

YOU AND THOUSANDS of other Air Force members are involved in maintenance to keep our complex aerospace equipment ready for use. You are part of a worldwide maintenance program. About 37 percent of all personnel in the Air Force are in this program and consume about 40 percent of the fiscal buget. Air Force maintenance responsibilities include all aircraft, missiles, AGE, weapon systems, ground communications and electronics, simulators, trainers, and precision measurement—everything except ground vehicles and real estate. You can see, therefore, that a function of this magnitude demands streamlined management and strict attention to detail.

In this chapter we will describe the makeup of a maintenance management organization and emphasize the importance of providing the maintenance data collection system with accurate and exacting data. Without this detailed knowledge and an appreciation of the Air Force maintenance system, there would be chaos in all maintenance organizations.

While studying this chapter, you should remember that any organization must be flexible enough to meet changing needs. The organization of maintenance activities directed by AFR 66-1, *Maintenance Management Policy,* will be revised, when needed, to meet the demands of our changing times. Some of the details you study here may change in time, but if you understand the basic information, you will be well-equipped to adjust to these changes.

5-1. Functions of Chief of Maintenance

Maintenance organizations vary greatly because of the mission, assigned equipment, location, and size of each organization. Though shops performing similar jobs among the major commands differ in organizational structure, any maintenance organization needs certain elements. One of these elements is a chief of maintenance and his or her staff.

029. State the primary function of the chief of maintenance.

Let's assume you have been elevated to the position of chief of maintenance. You are at the highest level of operational control. What are the duties of your job? First, you are the executive manager of your maintenance organization with the centralized control and direction of all functions of the activity. The maintenance staff agencies assist you, acting in the name of the chief of maintenance on those matters for which they have been given responsibility. In the maintenance manager concept (upon which the Air Force maintenance system is based), the chief of maintenance (you), through your staff functions, plan, control and schedule maintenance. For example, skilled mechanics with special equipment are sent out to do a highly technical job. Putting them where they are needed requires a system of scheduling, priority assignments, and dispatch and control action from a central agency—the chief of maintenance. We will discuss each staff agency individually so that you can grasp the general management concept and the special function of each agency. Understanding the basic responsibilities in your organizational structure is a necessary part of the training of each officer, enlisted member, and civilian in the Air Force.

As the chief of maintenance, you are a manager. You run the maintenance organization in accordance with policies and procedures outlined in AFR 66-1. You must apply the principles of leadership and management, and expect your supervisors to do the same. You and your staff must provide direction and guidance for all subordinates in the maintenance organization. This direction must comply with local and higher authority policies and instructions. You must be capable of estimating and programming facilities, equipment, manpower, and training requirements through study and analysis of the organization.

Exercises (029):

1. What is the overall function of the chief of maintenance?

2. How does the chief of maintenance fulfill his or her responsibilities?

5-2. Chief of Maintenance Staffing

Special staff elements consisting of Administration, Production Analysis, and Logistics Support are charged with the management support functions. These functions are not specifically related to the direct control of maintenance production. The functions of the chief of maintenance, which are related to the direct control of maintenance pro-

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duction, will be done by Maintenance Control and Quality Control.

030. Cite staff functions under the chief of maintenance.

Administration. This staff function is the administrative center for the maintenance organization. Its duties include the preparation and maintenance of reports, correspondence, local maintenance operating instructions (MOIs), and the control of keypunch services. It is the focal point for all correspondence and reporting.

Production Analysis. Production Analysis is the primary management information source for the chief of maintenance. It operates as a data surveillance and statistical unit. Its overall objective is to improve the maintenance operation by examining various maintenance management output products and reports to identify trends that are developing. Raw data alone can be misleading and must be carefully analyzed by production analysis personnel before it is used by management.

Logistics Support. This staff function provides overall knowledge of new programs and their impact on existing maintenance resources to the chief of maintenance. In addition, in insures that logistics support is on hand to meet the needs of the new program.

Maintenance Control. The maintenance control function plans, schedules, monitors, controls, and provides support for maintenance production. It determines and authorizes the expenditure of manpower and materiel within the maintenance activity. Maintenance Control has three subfunctions: Job Control, Material Control, and Plans and Scheduling.

Job Control. Job Control directs and coordinates the maintenance production effort. They control all maintenance actions which will cause an equipment status report (equipment is inoperative or limited). They control maintenance by issuing a unique job control number (JCN) for each action or job and by maintaining the status of the job as it proceeds. For each JCN issued, Job Control initiates a job status document (JSD). This form is used to document all information pertaining to the job: equipment outage time, nature of the problem, expected completion time, and, finally, the actions taken to correct the deficiency.

Materiel Control. The people in Materiel Control insure that the proper parts, tools, and equipment are available to the maintenance activities in the required quantities and at the proper time. They are the coordinating agency between Maintenance and Base Supply for the establishment of bench stocks, prepositioned spares, special levels, and supply point items. They also procure time compliance technical order (TCTO) kits.

Plans and Scheduling. This function produces the maintenance plan and preventive maintenance inspection (PMI) schedule from known requirements and maintenance resource information. This plan guides the production effort toward efficient and high-quality maintenance by a schedule of predicted activity balanced against resources.

Plans and Scheduling also keeps maintenance historical data. It maintains and administers official historical records, completed JSDs, and TCTO records.

Quality Control. Quality Control is concerned with the quality of maintenance performed within the activity. It identifies and resolves problems through a monitoring program. Some of the specific responsibilities are:

a. Technical publications—Set up and maintain technical orders, commercial manuals, and specialized publications.

b. Materiel deficiency reporting—Analyze and report deficiencies to the chief of maintenance.

c. Inspection—Determine the quality of maintenance accomplished within the complex.

d. Maintenance training—Be the focal point for maintenance training.

e. Standardization and evaluation—Determine the competence of maintenance personnel through the maintenance standardization and evaluation program.

Maintenance standardization and evaluation program (MSEP). All personnel who perform maintenance are subject to MSEP, except contractor personnel, Air Force engineering technical services personnel, and technicians assigned to command-designated maintenance teams. The evaluator selects and assigns tasks to be performed and then rates the technician's performance on each task as satisfactory or unsatisfactory. Evaluations are conducted when new or modified equipment is installed, when a technician has failed a previous evaluation, or as directed by the chief of maintenance to check the adequacy of training.

Technical inspections. Quality Control performs technical inspections to evaluate the quality of maintenance performed on assigned equipment. They are also useful in identifying training deficiencies and potential problem areas.

Activity inspections. Quality Control inspects each management support function, staff function, and work center at least once a year. Some areas of coverage are:

a. Procedural compliance with AFR 66-1, *Maintenance Management Policy,* and associated directives.

b. Equipment status reporting and maintenance data collection.

c. Compliance with prescribed safety rules and procedures.

d. Supply discipline, bench stock management, and repairable processing.

Special inspections. Special inspections are requested by either the work center or maintenance supervisor, or are directed by the chief of maintenance, commander, or higher headquarters. Some of the uses of special inspections are:

a. To investigate known or suspected management problems.

b. To identify problem areas after unsatisfactory corrective action.

c. To insure upon initial issue that incoming precision measurement equipment meets TO configuration and physical serviceability requirements.

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Exercises (030):

1. What unit is responsible for determining and authorizing the expenditure of manpower and material in the maintenance activity?

2. What part does the administration function play in the maintenance management program?

3. What is the purpose of Production Analysis?

4. What function is the focal point for maintenance training?

5. Name the three sections that make up the maintenence control function.

6. What information does the logistics support function provide for the chief of maintenance?

7. State the purpose of Job Control.

8. What is the function of the materiel control section?

5-3. Maintenance Data Collection System

The maintenance data collection system provides a way to record production credit for all tasks that use direct labor. This record is maintained on AFTO Form 349, Maintenance Data Collection Record. The first use of the information compiled by this system is for base-level management within the chief of maintenance complex. This information is also used at intermediate and major command headquarters. This system is continuously becoming of greater importance to the Air Force. The same recorded elements of data used by base-level management are used extensively throughout the Air Force Logistics Command (AFLC) for many purposes. Some of the specific uses by AFLC are:

- Analysis of each air traffic control radar system for those items that have high failure rates and that are high consumers of man-hours.
- Identification of unsatisfactory items and substantiation for product improvement actions.
- Analysis of established inspection requirements and a basis for adjusting inspection criteria.
- Analysis and adjustment of the component time-change cycles.
- Analysis of component/item data to screen out unsatisfactory units.
- Analysis of the not-reparable-this-station (NRTS) listing.
- Computation of spares requirements based on usage.

031. Point out your responsibility in the production of valuable maintenance data and define some of the terms used in its production.

Responsibility. How do you fit in the picture and what can you do to help the system work? Every time you work on the radar equipment in your unit, you enter what you have done on an AFTO Form 349. Summaries and computer runs are based upon the information you entered on the AFTO Form 349. So you see that the intelligence that scores of people will pick up from maintenance summaries depends entirely upon you and other workers who are maintaining equiment. The input items on the 349s identify the work required, the work done, the activity doing the work, the end item identification, why the work was required, when the requirement was discovered, the operating time, how many hours the work took, the persons who did the work, and many other essential facts.

Coding procedures are employed in this system so that the information can be processed through punchcard accounting machines and computers to produce summary reports and analysis products. Every prescribed form used in the system has space for specified coded information about the work being performed. The codes are alphabetic or numeric characters that represent standardized conditions, actions, and systems. A limited capability has been provided for the major command or local authority to collect additional data peculiar to its need. These codes make it possible to reduce extensive descriptive narratives to a number of short code symbols which can be "read" by accounting machines.

We already mentioned that you code your own forms. You must refer to the work unit code manuals and other sources to determine the proper codes. The job supervisor and the work center supervisor are responsible for making certain that all maintenance data forms are complete and accurately coded. The increasing use of this information in all elements of the Air Force makes it mandatory that supervisors insure accurate recording. Incomplete or inaccurate maintenance data will result in erroneous manning, equipping, budgeting, recording, and requisitioning at higher levels of command.

The information is recorded on the forms; then it is punched into cards, either in the maintenance complex or at statistical services, depending upon how local keypunching facilities have been allocated. These cards are then mechanically processed periodically by statistical services to produce reports for use in the management of the maintenance function.

It is very important that the codes entered on the maintenance forms be accurate and clearly written so that the

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keypunch operators can read and enter them into the punchcards correctly. The reports produced are significant only if the cards are accurate.

Terms. Some of the terms that we use in the remainder of this chapter may be new to you. Since they appear from time to time in instructions in TOs as well as AFR 66-1, you should become familiar with these terms because they directly affect the maintenance activity. One term is "unit of work." A unit of work is a job that has a definite beginning and end. The fixing of each malfunction is considered to be a unit of work. A second term is "time change," used in reference to certain components on equipment. These time-change components have a fixed life expectancy of a definite number of hours of operation, or a definite time period, or a fixed number of cycles of operation. A third term is "time significant." This term must not be confused with time change. A time-significant item is an item about which a study is being made to determine its life expectancy. A fourth term is "serially controlled." AFLC is concerned with the extent of modification of certain items. Therefore, AFLC demands reports on the operating time, modification, and repair of these items by individual item serial number. This information is reported when these items are removed from the equipment. The items on which these reports are made are called *serially controlled* items. Information concerning maintenance actions must be recorded "somewhere" for statistical services to receive the information it requires. The "somewhere" is on the AFTO Form 349.

Exercises (031):

1. State your chief responsibility in the production of maintenance information.

2. What is meant by the term "unit of work"?

3. To what does "time change" refer?

4. Describe a "time-significant" item.

5. What are "serially controlled" items?

032. Determine the correct information for selected blocks in AFTO Form 349.

AFTO Form 349, Maintenance Data Collection Record. This form contains 30 blocks, some of which are divided into a number of smaller sections. (See FO 2 in the back of this volume.) Because of the varied types of equipment used by the Air Force, the recording procedures cannot be identical. Standard recording procedures are prescribed to the extent that it is practical. The 00-20-2 series of technical orders contain the detailed instructions on the blocks to be filled out by each maintenance section.

To get a clear understanding of each block, we will discuss the general information to be entered, omitting the conditions under which it may be required. This you will learn through actual work experience with the forms. Remember that the 00-20-2 series of technical orders are the governing directives.

The job control number that you enter on the AFTO Form 349 is assigned by Job Control. If several work centers participate in the same repair action, all actions taken are considered part of the job and carry the same job control number.

The work center block always contains the work center of the individaul performing the work. If two work centers are involved in the action, two forms are required, one for each work center. The work center designator is a standard 5-digit USAF work center code established under the provisions of AFR 66-1.

The ID/serial number entry (block 3) on the 349 is a 6-digit number that identifies a specific type of equipment. If no 6-digit number is established, enter the end item serial number in block 3 and the mission, design, and series (MDS) in block 4. Also, enter the applicable SRD (standard reporting designator) code in block 5, and complete column L. The SRD code is found in the 00-20-2 series technical orders. Fill out the MDS block with the end item joint electronics-type designator (JETD) of the equipment, excluding the AN prefix. For equipment not assigned a JETD, and for all COMSEC and cryptologic equipment, enter the end item work unit code (WUC) preceded with two zeros. Column L, command account ID, is a two-position command code of the owning command from AFR 300-4, Volume 2 for classified or Volume 3 for unclassified.

An entry is required in block 6, TIME, only for removal and replacement of items identified by an asterisk in the WUC manual. When applicable, enter the equipment time to the nearest whole hour, or the number of cycles or calendar time from the applicable documents on which time or cycles are maintained. Essentially, what we're talking about here is documentation of time-significant and time-change items.

The priority of the work is entered in block 7 when the repairman has to be dispatched. No entry is required in block 8.

The only time that an entry is made in block 9, Location, is when the AFTO Form 349 is used as a dispatch form. If you are dispatched to perform maintenance, enter in this block the actual location where the work is performed.

Blocks 10 through 13 are not used for shop documentation. Blocks 14 and 15 are used at the discretion of local management.

Block 16 has been provided for a tenant support special-activities identifier. Its use is optional. If used, you enter the locally developed two-character (alpha or numeric) code that identifies support for nonreporting work centers or for special-activities/projects. Using this block is the only method of identifying those hours expended by a host performing support work for equipment assigned to other activities.

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No entry is required in block 17, Time Specialist Required, unless the AFTO Form 349 is used as a dispatch form. Likewise, an entry in block 18, Job Standard, is required only if the form is used as a dispatch form. If the form is used to dispatch a specialist to perform maintenance, the standard/average time required to perform the job is entered in block 18. If no job standard has been established, the estimated time required to complete the job is entered.

In block 19, you are required to enter the Federal Supply Classification (FSC) code for the item being removed for off-equipment work.

When off-equipment (shop) work is performed, block 20, Part Number, must have an entry. Normally, this entry is the part number of the item(s) on which work is being performed. You must give special care to recording part numbers. Omissions, improper positioning of dashes or slashes, inclusion of dashes or slashes when not applicable, incorrect recording of digits, and omissions of assigned modification dash numbers cause an unwarranted shredout of data for like items in base level and AFLC products. Exceptions to part number reporting and specific instructions for entries required in block 20 are:

a. The first preference for the block 20 entry is the manufacturer's part number for the component or complete assembly as it appears on the data plate. If the item does not have a data plate, get the item part number from the parts catalog.

b. If a complete assembly consists of subassemblies with separate data plates, enter the part number from the data plate of the complete assembly in block 20. If no data plate for the complete assembly is provided, enter the part number of the primary subassembly in block 20 to reflect reporting action against the complete assembly.

c. For those items that do not have part numbers, enter the NIIN (last seven digits of the national stock number) in block 20. Enter NSL (not stocklisted) in block 20 for locally manufactured items that are not stocklisted.

Block 21, Serial Number/Operating Time, is used for two different entries, serially controlled items and elapsed-time and time-change items. For a serially controlled item that is removed or being modified, enter the serial number of the item. If the serial number exceeds ten positions, enter only the last ten positions. When the serial number is entered as the identifying number, line out the Oper Time portion of the title to show that the entry is a serial number.

An entry in block 22, Tag No., is required when a serially controlled or time-change item is removed. If installation is accomplished separately from removal, a suspense copy AFTO Form 349 is created. The original job control number is entered in block 1, and the last three digits of the AFTO form 350 tag number are entered in block 22 of the suspense AFTO Form 349.

When serially controlled items or time-change items are being installed, enter the part number of the item in block 23, Inst. Item Part No. Enter the serial number of the installed item in block 24, Serial Number. In block 25, Oper Time, enter the previous operating time of the item being installed. You can obtain the information for blocks 23, 24, and 25 from blocks 11, 12, and 8 respectively, from the AFTO Form 350 (FO 3 located in the back of this volume) that is attached to the item being installed.

The center portion of AFTO Form 349 is divided into five horizontal action lines (1 through 5) and into 15 vertical columns (A through N). These lines and columns permit you to record up to five maintenance actions on a single form, thus reducing the number of forms on which basic identification information must be recorded. If one of the maintenance actions recorded on lines 1 through 5 involves a discrepancy that requires bit-and-piece replacement of nonreparable/nonrecoverable items, the identification of the component is recorded in block 29 (reverse side of AFTO Form 349).

Exercises (032):

1. If the equipment you are working on has no ID/Serial number, what entry is required in block 5 of AFTO Form 349? Where do you locate the information for this entry?

2. When is an entry required in block 6 of AFTO Form 349?

3. When is an entry required in block 17 of AFTO Form 349? What entry is made?

4. What is the first preference entry for block 20 of AFTO Form 349?

5. When is the serial number entered in block 21 of AFTO Form 349?

6. What information is entered in block 22 of AFTO Form 349?

033. Give the correct information for specified blocks of AFTO Form 350.

AFTO Form 350, Reparable Item Processing Tag. This form is required on components removed from end items and on subassemblies removed from components that require separate shop processing. The AFTO Form 350 (see FO 3 in back of this volume) identifies the origin of the part. It also contains key data elements needed to document shop actions on a shop-generated AFTO Form 349. The AFTO Form 350 is also used as an off-base identification tag when not-reparable-this-station (NRTS) action is taken. It is a two-part form. Part I is the actual processing document and

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Part II is the reparable processing center (RPC) scheduler's control document.

The maintenance person who removes the component from the radar unit initiates the AFTO Form 350. Blocks 1 through 14 can be filled out with AFTO Form 349 information, such as the job control number, serial number of unit, when discovered, how malfunctioned, part number, and discrepancy.

Block 15 is used for a brief description of the work done on the part, if the item was made serviceable. If the item is not reparable at your station, stamp NRTS and include the NRTS code in this block. If you use NRTS code 1, you must give the authority for declaring the item NRTS.

Part II of the front side of AFTO Form 350 is completed by Production Control/RPC, and detached and retained by that function as a record copy until the item is returned from the repair shop. The entries required on this side are merely copied from similar entries on the top front side of the form. Blocks 20 and 22 are the exception. When the repair is completed by the shop or the item is declared NRTS, the Action Taken code from column D of AFTO Form 349 is entered in block 20. Block 22, RPC Use Only, is for local use.

The back side of AFTO Form 350 contains more spaces; some wil concern you; others are of no interest to you as a mechanic.

Let us cover the first four blocks. The national stock Number is entered in block 23. When a component is determined to be in NRTS status, the base stock record account number (SRAN) code is recorded in Block 24 by the shop concerned or RPC. Block 25 is for supply only, and block 26, Serviceable, is used by the agency responsible for returning the item to a serviceable status. A stamp or signature and a dated entry are acceptable.

Entries are not required in block 27, Condemned. The item will be tagged with a DD Form 1577-1, Unserviceable (Condemned) Label—Materiel, Block 28, Supply Inspector's Stamp, is reserved for supply use only.

The person who removed the component from the end item (initiator) enters in block 29 and the date he or she removed the component. The reparable processing center production scheduler is responsible for making the entries in block 29, Base Repair Cycle Data. This is on the back side of Part II of AFTO Form 350. These entries show the date the item was received by RPC and indicate status changes for the unit. Example: To Shop, To Await Parts (AWP); To Awaiting Maintenance (AWM) (with corresponding dates). Dating makes possible the computation of "AWM time."

Part II of the AFTO Form 350 tag is more important than most maintenance personnel realize. This piece of the AFTO Form 350 tag is used by RPC to collate data on equipment usage. For example, if a particular item is repaired or worked on three different times in a certain time period, RPC should take steps to have another "like" item kept on base in Supply. If Part II of the AFTO Form 350 tag is used properly, you should have an extra component kept in Supply for each item that has shown up as a high-use item. You could have an entire spare radar set, in pieces, kept on base. AFTO Form 350 tags show Supply where the equipment usage is, and if you need something often enough to justify the expense of procurement and storage, the supply system will get it for you.

As you get experience with this form, as with AFTO Form 349, you will learn more about its use and the entries required.

Exercises (033):

1. Where do you obtain the information for blocks 1 through 14 on AFTO Form 350?

2. What entry is made in block 15 of AFTO Form 350?

3. Who is responsible for Part II of AFTO Form 350?

4. Who is responsible for the entry in block 26 of AFTO Form 350?

5. What does an entry of AWP in block 29 mean?

6. How must the back of the AFTO Form 350 be annotated to show an item unserviceable/condemned?

034. Explain selected terms that apply to processing and controlling equipment.

Processing and Controlling Equipment. Materiel Control has the responsibility for processing and controlling the parts, tools, and equipment that are needed by the maintenance activity. It must see that the required quantities of tools, parts, and equipment are available at the proper time. Without this function of maintenance management, individual technicians would lose a great deal of time trying to locate available items when they need them. The basic requirement for fulfilling these responsibilities is the ability to forecast the supply requirements of each maintenance activity with effective followup procedures to insure that plans and schedules will not fail or be delayed for lack of supplies.

Materiel Control keeps all maintenance activities informed of the overall supply situation, recommends improvements of supply support, and recommends equipment redistribution when inequalities exist. The efforts of this activity must be continually directed toward increasing the maintenance output. If materiel cannot be supplied through normal channels, Materiel Control, working with Supply, investigates all possible sources for the needed items.

Materiel Control makes a continuing study of supply action to discover the factors that cause supply delays. Each delay must be analyzed and brought to the attention of the

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appropriate personnel for correction. It must make every effort to provide the required items at the work location at the proper time without loss of maintenance and man-hours.

Critical items. Critical item lists are maintained by base supply in coordination with the Materiel Control. These lists are reviewed periodically to aid supply in determining supply and repair action. Critical item lists are used to keep both Production Control and Supply informed about the status of critical items in the repair cycle. Critical items are designated by AFLC, by the major command, or by the local chief of supply. Also, any item creating two or more MICAP (mission capable supply) reportable conditions or two or more cannibalizations in a 30-day period should be considered by the critical item monitor for inclusion in the base critical item listing.

A critical item is identified by the word "Critical" appearing on the issue document from Supply. Any item identified as critical must be delivered promptly to Production Control when it is removed from the end item. Production Control is then responsible for entering the item into the repair cycle with the proper priority.

Repair cycle assets. Another category of supply property is the repair cycle assets. This category includes all equipment that requires bench checking and/or repair. Equipment that is bench checked and found serviceable or is repaired and restored to serviceable condition is stored in supply warehouses or at other suitable supply points, as determined by base supply in coordination with Materiel Control. The primary purpose of these supply points, managed by Base Supply, is to facilitate maintenance support. Not all items in the repair cycle are stocked at these strategically located supply points. It is not entirely up to Supply to decide what items are to be stocked there. Materiel Control assists Supply in determining the line items and quantities needed at the supply points. This determination is based upon the need and frequency of need of a particular item, as indicated by past usage. Maintenance personnel normally request (or order) repair cycle asset items directly from Supply by telephone, radio, or document (request for issue form) as dictated by the urgency of the requirements.

The term "preplanned requirements" is applied to items, other than bench stocks, that are required for replacement during forthcoming periodic inspections. Normally, such items include those that are directed by technical orders for a time change plus those known to require replacement but carried forward to the periodic inspection.

Preplanned requirements serve a two-fold purpose in the overall support program. First, a standardized system is provided for forecasting a part of the maintenance requirements. This lets supply personnel review their available assets to determine whether they have sufficient stock to meet a known requirement. Second, supply personnel can submit special requisitions to depots well in advance of needs.

Time-change requirements. The records activity ascertains the time-change requirements and refers such information to Materiel Control. Materiel Control consolidates these time-change requirements and furnishes the data to Supply. It also determines the physical availability of items if such information must be considered in maintenance planning and scheduling.

The items and quantities needed for time change are verified by the records activity representative. This verification is particularly important to insure that items, previously listed for change but not replaced because of failure, are removed from the list.

Upon verification of these requirements, Materiel Control determines the availability of the items and notifies the maintenance chief so that replacement items can be placed on the inspection sequence chart.

Cannibalization. Another responsibility of Materiel Control is keeping records of cannibalization. Cannibalization is the removal of a specific assembly, subassembly, or component from one equipment end item for installation on another equipment end item. Cannibalization is authorized only to meet priority requirements, and only then with an obligation to replace the removed items.

When cannibalization is necessary, Job Control will request approval from the maintenance control supervisor or representative. Approved cannibalization actions will be directed and controlled by Job Control, and documented by Materiel Control and the work center. Materiel Control uses an AF Form 2414, Verification Worksheet, while the work center uses the AFTO Form 349.

Exercises (034):

1. Give the two reasons for listing items on the critical item list?

2. What types of supply property are considered to be repair cycle assets?

3. What are preplanned requirements?

4. What is meant by the term "cannibalization"?

5-4. Materiel Deficiency Reporting System

No system is perfect. We are all familiar with the recall of automobiles to correct their deficiencies. The Air Force is no different. From time to time, a piece of equipment is found to have contributed to an accident or incident or created a safety hazard. Some of these items are caught through an analysis of the maintenance data collection system. The Air Force also depends upon each individual to report materiel deficiencies. The responsibility for clearance and control of materiel deficiency reports is assigned to Quality Control. If you ever have to make out one of these reports, check TO 00-35D-54, *USAF Materiel Deficiency Reporting and Investigating System,* to make sure you have the latest information. Also, be sure to check with your quality control section for up-to-date advice on materiel deficiency report-

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ing. Let us see what type of reports are available and how they are defined.

035. State the purposes of the materiel deficiency reporting system, and identify the report to be used for given deficiencies.

Occasionally, deficiencies develop that require immediate reporting so that (1) the same deficiencies can be corrected on like equipment at other installations and (2) improvements can be made in design, test, and modification programs. Details for reporting materiel deficiencies under this sytem are in TO 00-35D-54, *USAF Materiel Deficiency Reporting and Investigating System.* To report materiel deficiencies, two reporting categories are available with three possible reports. These are the Category I Report, the Repeat Category I Report, and the Category II Report.

Category I Report. Thi sis a report of emergency conditions of a safety nature on all types of equipment. The four emergency conditions are:

(1) Accident or incident.
(2) Nuclear safety deficiency.
(3) Critical safety deficiency.
(4) Explosive safety deficiency.

Accident or incident. This is an unexpected event that does damage or could cause damage to persons or property. The accident or incident is not caused by enemy action.

Nuclear safety deficiency. This is any materiel, engineering, or procedural deficiency that could cause (or contribute to) a nuclear accident, incident, or deficiency. Such a deficiency can be reportable both as Category I and as a *DULL SWORD* (flag word for nuclear safety deficiency). If this happens, the submitting organization may submit a combination Category I and *DULL SWORD.* AFR 127-4, *Investigating and Reporting U.S. Air Force Mishaps,* spells this out. You must submit a combined report within 48 hours.

Critical safety deficiency. This type of deficiency exists when there is a malfunction of a part, component, or installation, causing a hazard that requires quick corrective action.

Explosive safety deficiency. This fourth deficiency presents a known or suspected danger to personnel and equipment. It can be caused by a malfunction, unintentional acts, and the detonation of ammunition or an explosive during use, handling, or storage.

Repeat Category I Report. This is a report of a deficiency that is determined to be identical to one previously submittd as Category I within the past 12 months. The first deficiency is still under investigation.

Category II Report. This category identifies two main deficiencies. The first deficiency covers nonwork unit coded items, and the second covers quality deficiencies in materiel. Category II conditions cover degrees of risk thought to be tolerable within broad time limits.

Nonwork unit coded items. These are items with design and maintenance materiel deficiencies. These deficiencies do not have a safety impact, but if they are not corrected, prolonged use of the items could:

a. Constitute a hazard.
b. Have a negative effect on operational efficiency.
c. Reduce tactical or tactical support ability.
d. Reduce operational life or general service utilization of equipment.
e. Create economic problems (manpower and money).

Quality deficiencies in materiel. The second type of deficiency is charged to applicable publications, drawings, standards, technical orders, and errors in workmanship. Another possible deficiency is failure to provide or account for all specific parts, or the presence of other conditions that can be traced to nonconformance during manufacture, repair, modification, or maintenance.

Methods of Reporting. Standard Form 368 is used for reporting all materiel deficiencies except those that are thought to be in Category I.

Category I reports. Category I reports must be submitted by electrical transmission on DD Form 173-1, Joint Messageform. Use Category I Reports to report the conditions we have already identified. These reports instigate investigations that must receive the highest priority possible at the action and support points. In the case of grounding action or the removal from service of like items, continuous (round-the-clock) action must take place until the problem is solved.

Repeat category I reports. If the same deficiency occurs during the time a Category I report is being investigated, another Category I report must be submitted in support of the first one.

Category II reports. Submit Category II reports by mail. Use Standard Form 368, Quality Deficiency Report (Category II), to make these reports. Make these reports on the deficiencies previously described.

An Adequacy of quality report is a means of obtaining the Air Force's evaluation of the quality of work performed by contractors and specialized repair activities. Quality control personnel perform this evaluation. Make this report on Standard Form 368.

Conditions Not to be Reported. A table in TO 00-35D-54 lists the deficiencies, conditions, and equipment that should *not* be reported under the materiel deficiency reporting system. It includes deficiencies in TOs. If you recall the information you studied in Chapter 3, TO deficiencies are reported under the TO improvement program. Therefore, before submitting a report under the materiel deficiency reporting system, check TO 00-35D-54 to make sure that the deficiency should be reported under this system. The quality control section of the maintenance management system coordinates the materiel deficiency program.

Exercises (035):

1. Give two purposes of the materiel deficiency reporting system.

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2. What type of materiel deficiency report should be used to report a nuclear safety hazard?

3. When you have a DULL SWORD deficiency, how should you usually report it?

4. What type of materiel deficiency report is turned in to report a materiel deficiency caused by an error in workmanship?

5. What is the purpose of the Adequacy of Quality Report?

6. Why are TO deficiencies not reported under the materiel deficiency reporting system?

7. Name the maintenance management activity that controls and coordinates the materiel deficiency reporting system.

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Maintenance Principles

IN THE MODERN electronic field, operational requirements have placed unbelievable demands on electronic systems. Our equipment must be faster, more accurate, and must have performance capabilities unheard of even a decade ago. To do your work, you must thoroughly understand electronic principles and must be familiar with the operation of the equipment systems. You must know how to use schematics, wiring diagrams, and proper troubleshooting and repair procedures.

6-1. Safety Precautions

Many of the maintenance acts you are required to perform call for removing equipment from the rack. In this section, we will discuss some of the safety precautions you should observe while working around electrical equipment.

036. State the safety precautions to take when you are working with electronic equipment.

Handling Heavy Materials. A disregard of approved safety practices in handling heavy materials can result in serious injury. Know what your limitations are, how to lift properly, and when to seek help.

As a continuing safety precaution, always keep floors clean and free of grease and water. Keep aisles and stairways free from obstructions.

Make sure your footing is secure when lifting a heavy load. Lift from the squatting position with your back straight and your legs exerting the main lifting force. Lower the load the same way.

Do's and Don'ts. Almost all electronic equipment carries dangerous voltages. Although careful engineering minimizes hazards, you must keep your wits about you. If you have to work inside the equipment, turn it off first if possible. If you must make adjustments inside a unit with the power on, you must use extreme caution.

Do's:

a. Use screwdrivers with plastic or rubber handles when you are working around electricity.

b. Keep the area surrounding high-voltage equipment clear of all obstructions, such as tools, toolboxes, and other foreign objects.

c. Know the location of the main power switch.

d. Know the rescue techniques for electrical shock victims.

e. Ground your equipment before starting your work.

f. Work with a partner who knows the "do's."

Don'ts:

a. Rely on safety devices such as interlocks, high-voltage disconnect relays, or automatic circuit grounders.

b. Wear metal objects such as rings, identification tags, medals, wristwatches, glasses with metal rims, or bracelets when working near electricity.

c. Use metallic measuring rules, metal-cased objects, or metal tools near energized electrical circuits.

d. Work on high-voltage equipment alone.

Rescue Techniques. The first step in rescuing a victim from electrical shock is to break the connection between the victim and the circuit. If possible, do this by turning off the power. The next best thing is to remove the victim from the circuit without endangering yourself. Use a wooden board, rope, or some other nonconducting object if you can't turn off the power. As soon as you can touch the victim safely, apply artificial respiration (preferably mouth-to-mouth); closed heart massage is an important measure that may be needed. Use only approved procedures for both lifesaving aids.

Speed is essential. Any delay greatly reduces the victim's chances of recovery. Over 70 percent of those receiving artificial respiration within 3 minutes recover. A delay of just one minute drops the figure to 58 percent. If there is no heart or respiratory action and treatment is delayed 5 minutes, death is virtually certain. When you are alone, do not take time to go for help. Start artificial respiration and/or closed cardiac massage *immediately.* If the person can be saved, you can do it as well as anyone else. Don't stop even if the victim appears dead. Eight hours have elapsed, in some cases, before the victim responded. The only sure sign of death is rigor mortis, and only a physician should judge whether that condition exists. Above all, don't let the victim be YOU or one of your fellow airmen.

Exercises (036):

1. List two housekeeping safety precautions that should be observed before heavy equipment is moved.

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2. Before you work on electronic equipment, what should you do with each of the following: (1) your wristwatch, (2) your wedding ring, (3) a plastic-handle screwdriver, (4) metal pliers, and (5) your toolbox?

3. State the first step to take when a person is unconscious from electrical shock.

4. Explain how a victim should be removed from a voltage source.

6-2. Preventive Maintenance

The best maintenance is preventive in nature with potential problems detected and corrected before they have a chance to develop. Preventive maintenance consists of the measures taken periodically (or when needed) to achieve maximum efficiency in performance, to insure continuity of service, to reduce major breakdowns, and to lengthen the useful life of the equipment or system.

037. List the actions that preventive maintenance includes.

Preventive maintenance consists principally of inspecting, cleaning, and lubricating equipment periodically. It is aimed at discovering conditions that, if not corrected can lead to malfunctions requiring major repair. A typical example of this type of maintenance is the requirement for lubricating the bearings of a motor at given intervals. If this is not done, the bearings may become dry and burn up and possibly destroy the whole motor and other associated equipment. The purpose of the scheduled maintenance procedures applies to all electronic and electrical equipment.

Exercise (037):

1. List the usual preventive maintenance procedures.

038. Cite the coordination and the timing sequence needed in scheduling preventive maintenance.

In a typical preventive maintenance program, there are daily and weekly performance checks and observations to determine actual equipment performance and to compare that performance with optimum performance standards. Some checks can be made while the equipment is operating, others have to be made when the equipment is shut off. As a radar repairman, you will be concerned either directly or indirectly with scheduling, planning, performing, and evaluating preventive maintenance (PM).

Scheduling and Planning. The first thing you must consider is scheduling and planning your PMs is the base mission. Downtime or off-the-air PMs should be performed when the base flying mission is at a minimum. Maintenance Control obtains this information from the base operations office and your flight facilities office. It coordinates with these activities and plans for the optimum maintenance schedule.

The frequency of preventive maintenance inspections (PMIs) is predetermined by technical order workcards. This may lead you to believe there is no planning necessary from your section, but take a closer look.

You have been in the field long enough to know that the time, manpower, and equipment needed for PMs vary widely. Some jobs entail moving heavy equipment and may require additional help. The degree of difficulty varies from job to job, and the time allowed for completing the tasks is limited. So you can see that the radar supervisor must work closely with Maintenance Control in planning the maintenance schedule.

With the necessary information, Maintenance Control issues the preventive maintenance schedule covering all the routines that must be performed on the equipment. It should notify you of scheduled maintenance periods well in advance of the actual working period. This notice lets you modify schedules and bring in the necessary people and equipment to complete the tasks in the required time.

Exercises (038):

1. Why does Maintenance Control coordinate with the operations section when planning a preventive maintenance schedule?

2. What factor determines how often PMs must be performed on the equipment?

3. Briefly explain the necessity for the radar maintenance supervisor's close coordination with Maintenance Control in planning the PM schedule.

039. Point out the types of problems that can be identified during preventive maintenance.

Finding Problems During Preventive Maintenance. While you are performing preventive maintenance routines, you should be continuously alert to potential defects in the equipment, such as worn parts and overheated components. Find the cause of these defects and correct the trouble. If you perform PMs properly, you greatly reduce the possibility of future failures and malfunctions.

Technical manuals outline the step-by-step procedures to follow when you inspect, clean, and lubricate equipment. The purpose of this section is to acquaint you with the general principles upon which these procedures are based.

One of the most important steps in performing preventive or corrective maintenance is a complete visual inspection. Many defects in electronic equipment are found this way.

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You must inspect the equipment visually for discolored, burned, or cracked resistors and capacitors; loose connections; loose mountings; sluggish or dirty relays; overheated transformers and motor housings; defective insulators; and any other abnormalities in any other component. The importance of the visual inspection cannot be overemphasized. Make this inspection very carefully. Many simple troubles have been overlooked and correcting them has become time consuming because someone neglected to perform the visual inspection properly.

At times, potential troubles can be found by touch. For an example, feel the coupling transformers. They should be cool even after the equipment has been operating a relatively long time. If they are hot, something is wrong. The transformers in the power supplies should be rather hot, but not hot enough to burn your hand.

During the inspection, carefully note the areas that will require special attention when you start cleaning the equipment. You can remove most dust with a vacuum cleaner, but more stubborn dirt, grime, grease, and corrosion require other methods of cleaning.

The first step in cleaning electronic equipment is to remove dust, dirt, and foreign particles with a vacuum cleaner or compressed air. In cleaning with compressed air, be careful that it does not damage fragile parts. You can prevent damage by not using excessive air pressure and by carefully handling the air hose. A soft dustbrush has some advantages if you use it carefully. After you have removed the loose dirt from the equipment, use a clean lintless rag moistened with the *approved* cleaning solvent to remove any remaining dirt and grease spots.

Proper precautions must be observed in the storage and use of cleaning solvents. Some solvents are extremely toxic (trichloroethylene, for example) and should be used *only in a well-ventilated area.* Take care to know the hazards involved with any solvent you use. Besides toxic hazards, some solvents may have a deteriorating effect on thermoplastics, "doped" coils, or natural rubbers. Isopropyl alcohol or common commercial-type cleaners available from the LP store are safe and can be used to accomplish as good a job as many of the more toxic solvents.

Remove any corrision found during the visual inspection. Clean dirty, corroded tube or card pins and relay prongs with crocus cloth or fine (#0000) sandpaper and then wipe them clean with a dry cloth. Clean fuse ends and cable connector pins in the same manner.

For lubrication instructions, use the applicable equipment technical orders (properly called technical manuals) in your organization. Equipment technical manuals give you specific instructions about the types of lubricants to use, how to apply them, and the intervals at which they should be applied.

Exercises (039):

1. List the conditions you should look for during a visual inspection.
2. Describe the precautions that must be observed when solvents are used.
3. How can potential troubles be found by touch?
4. Briefly describe the procedures in a cleaning routine.
5. Where can you find information about the lubricants to use in a lubricating routine?

040. State the effects and treatment of climatic deterioration.

Climatic Deterioration Prevention and Treatment. The purpose of climatic deterioration prevention is to prevent arcing, frequency drift, short circuits, and the general deterioration caused by excessive humidity, condensation, and the resultant growth of fungi. These are constant threats to electronic equipment operation.

Some effects of climatic deterioration are:

a. Moisture causes swelling that may move the supports out of alignment, resulting in binding of parts.

b. Moisture provides electrical leakage paths, causing flashover and crosstalk.

c. Fungus growth reduces resistance between parts to such an extent that the parts are useless.

d. Rotting caused by moisture destroys protective material.

e. High temperature and moisture vapor cause rapid corrosion.

f. Different metals with different potentials cause electrolysis when moisture is present.

There is a preventive treatment which, if properly applied to electronic equipment, provides a reasonable degree of protection. It guards against fungus growth, moisture, corrosion, salt spray, insects, cold, desert heat, etc. The treatment consists of applying an approved lacquer or varnish coating with a spray gun or brush. The coating may be called moisture-fungus proofing (MFP) and should be reapplied whenever your work causes the old coating to be removed.

Exercises (040):

1. Name the two chief problems in climatic deterioration.
2. Explain how climatic deterioation causes crosstalk and flashover.

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3. What is the cause of electrolysis?

4. How can equipment be treated to protect it from climatic deterioration?

041. Identify the problem areas that you can discover by closely monitoring the preventive maintenance program.

Evaluation. Even though your personnel are very capable and have the work well defined, you or your supervisor should maintain a continuous monitoring program. This monitoring program will give you a complete record of maintenance progression and quality.

The recorded information will be very useful during future maintenance periods. Suppose you find that breakdowns are often isolated to the same item or unit. This problem requires a careful evaluation of the routines involved in the breakdowns. You may find that the routine is not being performed thoroughly or lacks certain steps needed to prevent a recurrence of the breakdown. You may have to recommend changes to the routine, increase the intensity of training in that area, or monitor more closely to insure that the routine is properly performed. Evaluation team reports and reports from inspection teams will also improve the effectiveness of your maintenance program.

A comparison of data taken on a particular piece of equipment at different times can reveal slow progressive drifts that are too small to be significant in any one test. While the week-to-week changes are slight, they should be followed carefully so that replacements or repairs can be made before the margin of performance limits is reached. Regard any marked variations as abnormal and investigate them immediately.

Another advantage of keeping systematic records of performance and servicing data is that maintenance personnel develop a more rapid familiarization with the equipment involved. The accumulated experience contained in the records simplifies the task of analyzing equipment malfunctions and serves as a guide to swift and accurate troubleshooting.

Exercises (041):

1. Place a checkmark in the space provided for each problem area you would expect to identify by monitoring the PM program.

   ____a. Damaged RF plumbing.
   ____b. Routines not being performed thoroughly.
   ____c. Routines needing changes.
   ____d. Repairmen needing training.
   ____e. Discolored, burned, or cracked wiring.

2. How can you detect a slow progressive deterioration of equipment that may not show significantly in any one test?

6-3. Corrective Maintenance

Corrective maintenance is defined as "returning equipment to operational status or serviceability." Obviously, returning equipment to operational status first requires locating and repairing the trouble. Locating trouble is commonly referred to as troubleshooting, and corrective maintenance in your area is "troubleshooting and repairing electronic equipment." Corrective maintenance procedures are outlined in the appropriate equipment manuals.

Because the air traffic control radar field includes a large number and variety of items of equipment, we can not teach you, here, how to apply corrective maintenance to every type of equipment. Instead, we will discuss the general principles of corrective maintenance.

042. Explain some of the safety precautions to observe in troubleshooting radio-active equipment, and, given a series of statements, determine which phase of corrective maintenance each relates to.

Safety Precautions. Troubleshooting can be a mind-tingling experience and can be the time you are most vulnerable to an accident. We will briefly point out some of the safety precautions you should observe while performing corrective maintenance.

a. If you must work around the antennas, be sure that the power is off and the transmitters are not radiating. Radio frequency (RF) radiation can cause burns beneath the skin and cataracts on the eyes. You can be injured before you feel any pain.

b. Be careful when you are handling radio-active tubes. Dispose of these tubes in accordance with the TO 00-110N series.

c. Always use a qualified safety observer. The safety observer must know how to turn off the equipment and be able to apply emergency first aid.

d. When grounding equipment for corrective maintenance, attach the ground at the point of repair.

e. Keep your work area clean and post appropriate warnings signs to alert other personnel to the fact that the equipment is being worked on.

f. Avoid using wooden-handle screwdrivers. They can absorb moisture, breaking down their insulating properties.

The preceding precautions should not be considered the only ones that require extra attention. Instead, they should be only a beginning as you learn and develop sound safety practices.

Troubleshooting. Troubleshooting is a process of elimination. There are indications that give definite clues as to where the trouble is. Begin by eliminating the components or circuits that are operating properly. You can eliminate some parts by observation alone, while the elimination of

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others requires test equipment. Every part eliminated brings you closer to the source of the trouble.

There are troubleshooting analysis charts in your technical manuals. These cover the malfunctions that occur over and over again in specific equipment. In addition to these common troubles, you will find many problems peculiar to the specific set (or system) on which you are working. Unusual problems force you to use your information resources and your experience to solve them. Thoroughly analyze every malfunction as a part of the troubleshooting procedure. This is a challenge that you must be prepared to accept; only on your own initiative can you succeed. In addition to the resources that we have already noted, you must know how to use the test equipment.

If you do not recognize symptoms of trouble through routine checks or reports, you will waste many man-hours. Without careful examination, you can overlook early signs of trouble. Many troubles can be spotted through indicator presentations, equipment meter readings, and performance reports. Some troubles, such as low receiver sensitivity, however, are not readily apparent and must be detected through periodic performance checks. To minimize downtime, you must develop a system of troubleshooting, including an examination of all available equipment records, an evaluation of the operator's comments, and the use of operational checks when possible.

Locating the trouble is usually the most difficult step in corrective maintenance and is, therefore, the one to which we give the most emphasis. A technician's troubleshooting technique is based on his or her knowledge of the operational standards and of the block diagram of the equipment. As part of the technique, you must be able to read and understand technical literature, such as cabling charts, schematics, and voltage and resistance charts.

The important things to remember in troubleshooting are:

a. Use your block diagrams.

b. Narrow the trouble down as far as possible with indications from the equipment itself.

c. Look for the most common troubles (fuses, misset controls) first.

d. In most cases, check voltages or waveshapes before measuring resistance.

e. Analyze the symptoms carefully before removing any components. A little effort in this direction can save a lot of time and labor.

f. Check the records. Do not overlook the importance of your fellow worker's previous experience. He or she may have encountered the same trouble that you must deal with.

Repair. Since each repair is an individual problem and differs from a previous repair in some respect, it is almost impossible to set up a routine or a production-line technique in dealing with reapris and to adhere to it. There are certain principles, however, that you should follow in all cases if you are to complete a repair with the least amount of time and expenditure of parts. These are:

- Correct the malfunction using the procedures outlined in the equipment technical orders and "general" electronic equipment maintenance technical orders.
- Check the overall equipment for any visible defects which, if not corrected, will eventually break down and cause a later malfunction of the equipment.
- Know how to obtain and requisition (bench stock, local purchase, supply channels) replacement parts needed for repair.
- Replace components parts with like items—*do not* attempt to substitute parts without first discussing this with your supervisor.

Circuit Alignment. It should be clear that it is impossible (or very impractical) to manufacture electronic components with no variation at all in their values. Of course, age, climatic conditions, vibrations, etc., can cause the values of components to change. Because of this, variable components provided in some tuned circuits require alignment. Thus, by a slight retuning or adjustment from time to time, the optimum performance specified in the maintenance manuals or by the manufacturer may be attained.

Reduced sensitivity or reduced output indicate a need for alignment, but alignment should not be undertaken until the equipment has otherwise been put into good operating condition. Every piece of equipment that is operating poorly requires maintenance, but it does not follow that every piece of equipment that needs maintenance also needs alignment. Sometimes, repairs that include the replacement of components or the redressing of wiring make later alignment necessary. Therefore, you should not attempt alignment until all problems have been corrected and all defective parts replaced. We cannot stress too strongly that *before* alignment is attempted, all available instructional or maintenance literature should be carefully consulted.

With today's equipment and maintenance concepts, such as line replaceable unit (LRU) troubleshooting, you will often be troubleshooting by pulling a card or subcomponent out and replacing it with another from a forward supply point. If the new circuit card you install is not aligned, you may be putting in more problems than you are taking out. Consideration should be given to inspecting and aligning items on forward supply point, before you need them for troubleshooting or repair.

Performance Testing. A performance test is a check to determine the condition or the operating efficiency of a piece of equipment. The first checks are performed when the equipment is initially installed. Such checks must continue to be made periodically (at the beginning of each shift, for example), at the conclusion of either preventive or corrective maintenance, and at any other time when there is reason to believe that the equiment is operating below accepted standards. At these times, you must check the equipment against the indicated performance standards in the technical manual, using the proper test equipment. These checks reveal improper or defective circuitry, and in many cases a simple adjustment can correct the malfunction that causes this condition.

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Exercises (042):

1. Explain the danger involved when wooden-handle screwdrivers are used for electronic work.

2. The success you achieve in troubleshooting depends primarily on _____.
3. Why is it difficult to set up repair actions on a routine or production-line technique?

4. In the space provided, identify the phase of corrective maintenance each statement relates to.

   a. Examine all available equipment records, evaluate operator's comments, and perform operational checks when possible.

   b. Post appropriate warnings signs.

   c. Insure that your work area is clean.

   d. Use voltage and resistance charts.

   e. Check the overall equipment for any visible defects which, if not corrected, will eventually break down and cause a malfunction of the equipment.

   f. Consult all available instructional or maintenance literature.

   g. Check to determine the condition or operating efficiency of equipment.

6-4. Modifications

From time to time, your equipment must be modernized so that it can meet increasing demands. In most cases, it is easier and less expensive to improve existing equipment than to design and build a new system. Safety hazards and recurring failures also demand equipment modifications. Let's look at the different classes and types of modifications and discuss where they come from and who has the responsibility for performing them.

043. Identify modifications by class and/or type.

Types. Time compliance technical orders (TCTOs) are grouped according to the importance and urgency of the work. The degree of urgency is indicated in the instructions by the time when the work must be done. Five types of TCTOs (including interim) are authorized.

(1) Immediate action is identified by a border of red Xs and the words IMMEDIATE ACTION printed in red at the top of the first page. Immediate action technical orders are issued because of unsafe conditions that could result in fatal or serious injury to personnel, extensive damage, or destruction of valuable property. Such conditions embody risks that are calculated to be intolerable.

(2) Urgent action has a border of alternately spaced red diagonals (/) and red Xs inclosed in a red circle and the words URGENT ACTION printed in red at the top of the first page. Urgent action technical orders are of combat necessity or are issued for potentially hazardous conditions that could result in injury to personnel, damage to valuable property, or reductions in combat efficiency.

(3) Routine action is printed on plain white paper without identifying marks. Technical orders of this type are issued to correct all deficiencies that would reduce the operational life and general use of the equipment. They are issued in categories which are based upon what level of maintenance (depot or organizational) is responsible and how long that organization has to comply.

(4) Record type is printed on plain white paper without distinguishing red marks. This type of TCTO does not provide step-by-step instructions for doing the work because the scope or complexity of the modification is such that a contractor or specific Air Force activity, higher than organizational/field-level maintenance, must do it. However, these TOs do describe what the modification consists of, tabulate the equipment affected, provide an index of all necessary drawings and instructions, and include a list of all parts required.

(5) Interim TOs are urgently needed instructions in interim form by means of a message of some type. Examples are radiograms, telegrams, teletypes, or airmail. Normally, an interim TO is replaced by a formal TO within 40 calendar days.

Classifications. We shall briefly explain how modifications are classified so that you will have an idea of the types that are of most concern to you.

Class I. This class covers the temporary removal of installed equipment that is not required for mission support (test scopes, additional PPIs, etc.). Such removed equipment must be kept available in serviceable condition for reinstallation so that the system or equipment can be returned to its standard configuration within 48 hours.

Class I also includes the temporary installation of equipment needed for a special mission or purpose (not to exceed 6 months) when AFSC or AFLC approved installation engineering is available and the equipment is in Air Force stock and available without additional procurement. The temporary installations must permit the system or equipment to be returned to its original configuration within 48 hours. Class I modifications must be removed before the equipment is transferred to another command.

Class II. This class covers temporary modifications required to support research, development or operational test, and evaluation programs.

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Class III. Class III covers modifications that are required to insure production continuity and do not qualify as Class IV or Class V modifications. This class may include the incorporation of Group B equipment originally programmed and procured but not installed during production. (We shall explain Group B equiment later.)

Class IV. This class covers three categories of modification. First are those required to insure safety of human life, systems, or equipment and protection from operational, nuclear, and biophysical hazards. If such safety hazards could ground the systems or equipment, seriously restrict flight or ground operation, or cause unacceptable risk to personnel if not corrected, then the equipment must be modified. Modifications of this type are designated Class IVA.

Second are modifications required to correct deficiencies that would result in unacceptable mission aborts or would seriously impede the accomplishment of the system/equipment mission. This category includes deficiencies affecting maintainability and reliability, electromagnetic compatability, and communications security. Modifications of this type are designated Class IVB.

The third is the Class IVC modification which would result in a significant improvement in maintainability or service life, or reduce operating costs.

Class V. This class covers the modification of a system or equipment that will produce: (1) a change in operational requirements or performance that provides an added capability not inherent in the baseline configuration, (2) the capability to accomplish an assigned mission that the basic system or equipment was not originally designed to accomplish, and (3) a significant and measurable training or logistic improvement certified essential by the command or agency primarily concerned.

Group A and B kits. To further identify the term modification and its classifications, we include the Group A and B kits or equipment. Group A kits are items, parts, or provisions permanently or semipermanently installed in a system to support, secure, interconnect, or accommodate an item of equipment. They may include racks, cabinets, etc. Group B kits are the operating components of the equipment which, when installed in connection with the Group A parts, provide a complete, operational installation. Normally, the Group B component is readily removable.

Exercise (043):

1. Match each of the following statements with its proper class or type of modification.

____a. To improve the basic system or equipment so that it will be capable of accomplishing a mission it was not originally designed to accomplish.

____b. Temporary modification to support research.

____c. Modification to improve maintainability.

____d. Modification to correct safety hazards that would seriously restrict ground operations.

____e. This TCTO has a border of red Xs.

____f. This TCTO is issued because of combat necessity.

044. List problem areas that need modification and the preparatory steps to take when installing modifications.

Modification Requirements. Now that you have learned the different types and classes of modifications, you should know why modifications are needed and who performs them.

The main source of information on equipment performance is the radar specialist in the field. Many areas in the maintenance environment become the basis for the submission of modification or change proposals. Some areas to consider are:

a. Any item or condition that may affect the well-being or safety of personnel.

b. Poor equipment performance, short equipment life, and early part failures.

c. A difficulty in removing or installing certain components, units, or parts, which can be remedied by a change in procedure.

d. Repeated equipment failure caused by the failure of one or more parts of the same type or make.

The above list is not all inclusive. It is only a small sample of areas that may need improvement.

If you decide a change is needed, discuss the change with the people in your section. They may have some ideas that could improve your recommended change. Making your idea a joint effort will motivate your coworkers to look for ways to improve equipment and procedures.

You may feel your idea is not perfect or you may think it has been submitted before, but the only way to know for sure is to submit it. All modification proposals are recognized. Some are used and some are not, but you can rest assured that your proposal will be evaluated by trained people to determine its value to the Air Force.

In cases where human lives are endangered, you must take immediate action. Modifying, changing, improvising, or substituting components can be used as a temporary measure. You may not know how to correct the situation, but you are obligated to report the condition.

In accordance with AFR 57-4, *Modification Program Approval,* Class I, II, III, and IV modification proposals are

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submitted through command channels to the command authorized to approve the proposals. Proposals are submitted in accordance with TO 00-35D-54, *USAF Materiel Deficiency Reporting and Investigating System,* or as otherwise directed by Headquarters AFLC/AFSC. Class V modification proposals (except military assistance program modification proposals) are submitted to the headquarters of the major command in which the proposals originate.

A large percentage of the modification proposals submitted by field personnel are caused by materiel or maintenance deficiencies and usually fall into the Class IV type. You will be mainly concerned with reporting materiel deficiencies in accordance with TO 00-35D-54.

Many of the modification kits that you have installed or will install are a direct outcome of the maintenance data collection system outlined in AFR 66-1. If the analysis of collected data indicates deficiency trends in materiel, then the facts must be investigated and appropriate corrective action taken to remedy the situation—usually in the form of time compliance technical orders (TCTOs). Your part in this system is the accurate and timely reporting of all maintenance data.

The knowledge-level requirements for performing modifications are more or less dictated by the TCTO. The TCTO lists who will undertake the work. For most modifications, the work is done by organizational/intermediate level maintenance. Since most ATC sites are authorized to perform both organizational and intermediate level maintenance, installing "mod" kits will be part of your responsibilities. Of course, the degree of supervision you will need is directly proportional with the complexity of the modification. Look at some preparatory steps to insure satisfactory installation of "mod" kit.

a. Inventory the kit.

b. Read the TCTO instructions. Make sure you understand them.

c. Check the TCTO to find out when the work must be completed.

d. Prepare for the job:

(1) Do as much precleaning and component removal as possible.

(2) Discuss the job with fellow workers to insure complete understanding of the task.

(3) Make sure you have the tools and test equipment necessary to complete the job.

(4) Check with the supervisor to insure that all coordination has been completed and the time needed to perform the task has been established.

Deviations from these preparatory steps may be dictated by instructions contained in the TCTO. An example of a deviation is an Immediate Action TO or a "mod" kit that must be installed by depot-level maintenance.

Don't assume that the modification is complete until you have made certain that everything is operating satisfactorily and that the modification is performing the function that it was intended to perform. Then record it and report it for maintenance management purposes.

Exercises (044):

1. List three problem areas that indicate the need for a modification.

2. List the preparatory steps to be taken when installing a modification.

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Soldering and Cabling Techniques

SOLDER IS ONE of the oldest, simplest, and most useful of all the metals in use as fusible alloys. It gives real service in today's electronics industry. Without this material to bond together components, circuit boards, and miniaturized circuit chips, we would still be in the preradio age. Soldering makes the electrical and physical connections to insure continuity for electron flow. Because of its very simplicity and ease of application, soldering has come to be regarded as something to be taken for granted. This should not be the case. Engineers and technicians have found that many failures attributed to electrical components were actually the fault of poorly soldered connections. Many investigations and studies have been performed on the "soldered connection." From the results of these studies, improvements and changes in the soldering technique have taken place.

7-1. The Nature of Solder

Any discussion of soldering techniques should begin with an explanation of solder itself. This generally accepted substance is quite simple, and is relatively easy to use when proper preparation, materials, and techniques are employed.

045. Name the different types of solders, fluxes, and explain their uses.

Solders. Ordinarily soft solder is a fusible alloy consisting essentially of tin and lead. When tin and lead are alloyed together, the percentage of tin to lead is expressed as a ratio, with tin as the first number. For example, 60:40 means that the tin content is 60 percent and the lead content is 40 percent. There are many classes of solder available with many uses, and they can be grouped as (1) flux-core, (2) solid-wire, and (3) bar solder. In our discussion of soldering, we will be referring to the wire-type solder with rosin flux-core and a tin-lead content of 63:37 or 60:40, unless otherwise stated.

The comparison of commercial solder covers the entire range of the tin-lead ratio. Pure tin becomes a liquid at 450° F., and pure lead becomes a liquid at 621° F. When the two metals are alloyed together, new liquefaction points are created, depending upon the tin-lead ratio.

Refer to figure 7-1 and locate lines AC and BC. Note that point C represents an alloy of the lowest melting point. The alloy at this point is 63 percent tin and 37 percent lead and is known as the *eutectic composition* with a distinct melting point of 361° F. A eutectic alloy has a melting point lower than that of any other percentage combination of the same components.

With the exception of 63:37, all solders in the tin-lead series are made up of ratios of these two metals and do not melt sharply at any one temperature. Instead, the different ratios pass through an intermediate range of plasticity before going into the liquid range. This intermediate range of plasticity also takes place in the process of cooling from the liquid to the solid state.

A working knowledge of the plastic range of solders will be helpful in selecting the type of solder needed for a specific job. For example, in plumbing, a wiping solder consisting of 50 percent tin is acceptable because of the long time such an alloy stays in the intermediate range of plasticity. On the other hand, in electronics, many components are heat sensitive and cannot withstand high temperatures for any length of time; so higher tin alloys with shorter ranges of plasticity are used.

Figure 7-1 shows that a tin-lead ratio of 60:40 is well suited for electronic soldering work. This alloy has a low melting point and a short time in the plastic range. These characteristics reduce the time and temperature you have to put on the connection. The 60:40 solder is primarily used in conventional circuits and terminals where the melting point and flexibility of this solder can be tolerated.

The 63:37 solder is much preferred for printed-circuit boards and miniaturized parts. Its sharp and distinct melting point, along with its negligible plastic range, makes the 63:37 solder ideal for jobs where heat limitation is critical. If, however, 63:37 solder is not available, you will find 60:40 solder a generally accepted substitute.

Solder Flux. Common metals exposed to the atmosphere acquire a thin nonmetallic film known as oxide. The longer the exposure, the thicker this film becomes. Oxide film forms an effective insulating barrier. As long as the nonmetallic barrier is present there can be no actual metal-to-metal contact. As a result, soldering action cannot take place.

The function of the soldering flux is to remove the oxide film from the surface of the metals and to keep it removed during the soldering process. The flux does this because its melting point is lower than the solder. As the flux melts, it first exerts a slight chemical-reducing action, loosening the trapped oxides on the metal surface. The loosened oxides, wet by the flux, coagulate and are suspended in the flux body. The solder then melts, floating the lighter flux and the impurities suspended in it to the outer surface and edges of the molten solder. Most of the flux is burned away during

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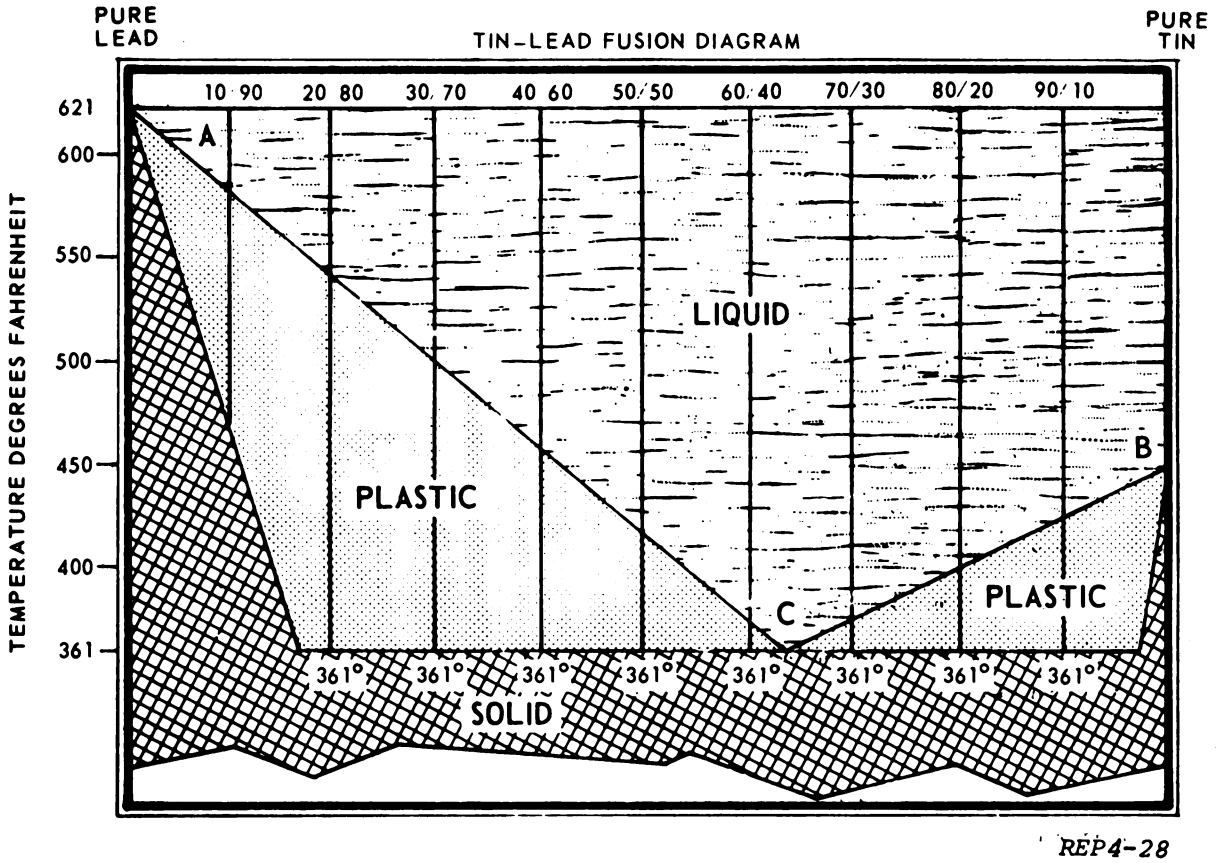

Figure 7-1. Tin-lead fusion diagram.

the soldering process, leaving only a small amount of tacky residue upon cooling. Because dust and dirt adhere to the rosin residue, you should clean each completed soldering joint before returning the equipment to operation.

It should be mentioned at this time that flux should not be expected to remove heavy surface oxides from metals. Heavy surface oxides, paint, shellac, sulphides, gross forms of dirt, and other inert matter must be removed by a mechanical or chemical cleaning process.

There are two classes of flux: corrosive and noncorrosive. *Zinc chloride, hydrochloric acid,* and *sal ammoniac* are in the corrosive class. Never use a corrosive flux in electronics repair work. If corrosive flux remains in the joint, in time it eats through the connection and creates a high-resistance circuit. All of your electronics soldering should be done with a noncorrosive, nonconducting rosin flux. Rosin flux is available in paste, liquid, and powder forms. Limit your use of liquid rosin flux to the following applications:

a. Removing excessive solder from a joint by wicking on a stranded wire.
b. Soldering nickel-plated wire.

If you use liquid flux with flux-cored solder, the two must be chemically compatible.

Exercises (045):

1. What types of solder are preferred for connections in electronic circuits?

2. Name the type of solder preferred when temperature limitations are critical.

3. State the purpose of flux.

4. Why should you avoid using certain types of flux when soldering electrical connections?

7-2. Tools and Equipment

Proper soldering and desoldering of connections in electronic equipment require certain basic tools and equipment.

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Your use of additional specialized tools will increase the efficiency of the operation and the quality of your finished product. Our discussion will be limited to specialized tools used in soldering and desoldering.

046. Specify the proper use of some of the specialized tools used in soldering and desoldering.

Insulation Strippers. Stripping the insulation from a wire is one of the first steps you take when you are preparing a wire to be soldered. Great care is needed to insure that the wire is not cut, nicked, or scraped in the process. For this reason, use a thermal stripper instead of a precision-cutting stripper.

Thermal strippers. Use thermal strippers (see Fig. 7-2) when possible and particularly on wire size 22 AWG *(American wire gauge)* and smaller. The stripper should have a controllable heat output to prevent blistering or melting the insulation excessively. Use an exhaust hood and fan ventilation system to dispose of toxic fumes when you are stripping such insulation as teflon, polytetrafluoroethylene, or polyvinyl chloride. Since it is not always practical to use a thermal stripper, the next best stripper is the precision-cutting type.

Precision-cutting strippers. Precision-cutting strippers (see fig. 7-3) can be used on wires larger than 22 AWG. Use these strippers to strip glass braid insulation but not to strip teflon-insulated wire. Precision-cutting strippers are not adjustable, but the blades are replaceable. These strippers should be checked periodically for proper operation.

Bending Tools. Wire-bending tools should have smooth bending surfaces so you can bend the component leads without nicking, scraping, or damaging them (see fig. 7-4).

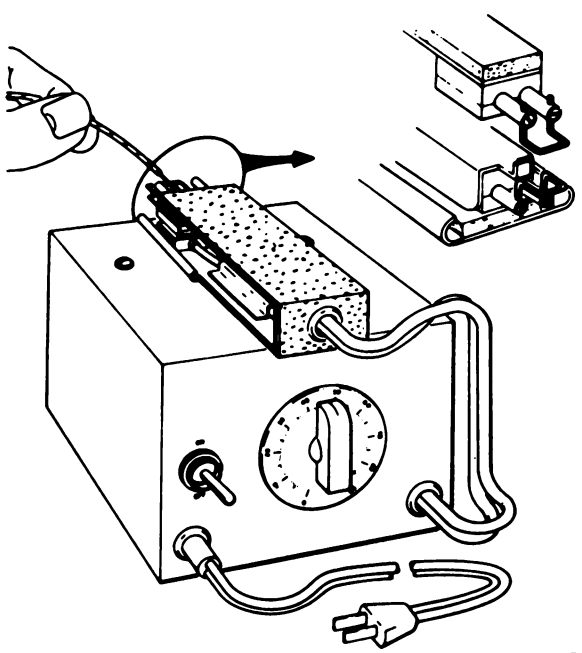

Figure 7-2. Thermal strippers.

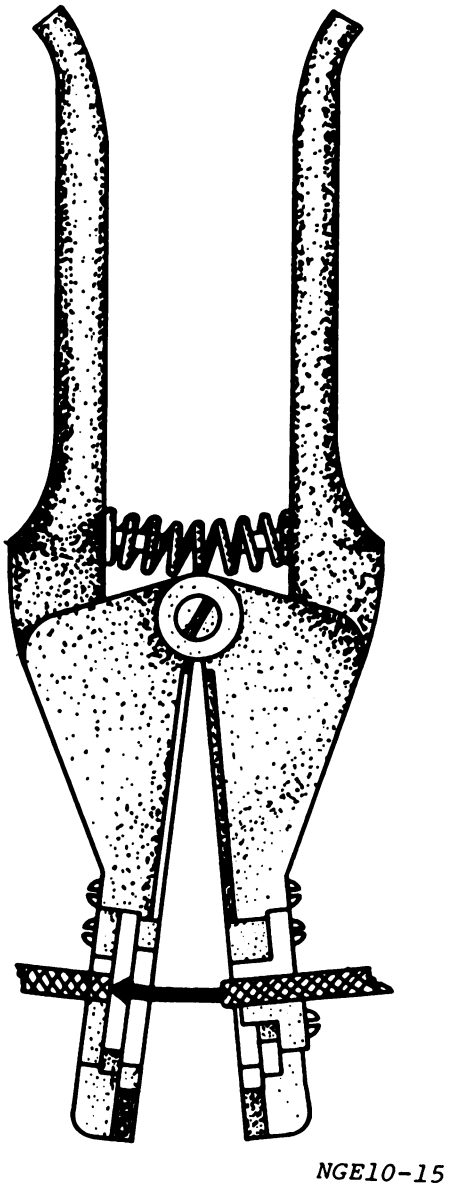

Figure 7-3. Precission-cutting strippers.

You can use standard needle-nose pliers for bending wires and component leads, provided the jaw tips are encased in covers of copper tubing, as shown in figure 7-4.

Thermal Shunts. During a soldering operation, use thermal shunts or heat sinks (see fig. 7-5), as necessary, to protect heat-sensitive components, such as semiconductors, crystal devices, meter movements, and insulating materials, from heat damage. A thermal shunt should be made of a material, size, shape, and design that permits rapid application and removal with minimum interference to the soldering procedure and rapid heat removal from the area being soldered. Hold thermal shunts in place by friction or spring tension, which will prevent damage to the wire surface, the insulation of the wire, and the component being soldered.

Cleaning Tools. Cleanliness is the key to reliable soldering. Remove all dirt, grease, and oxidation from the surface

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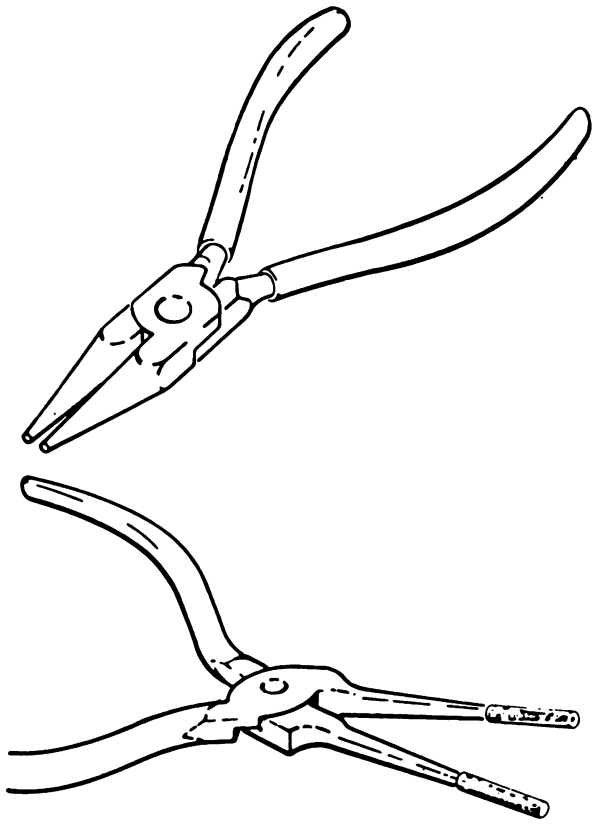

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Figure 7-4. Wire-bending tools.

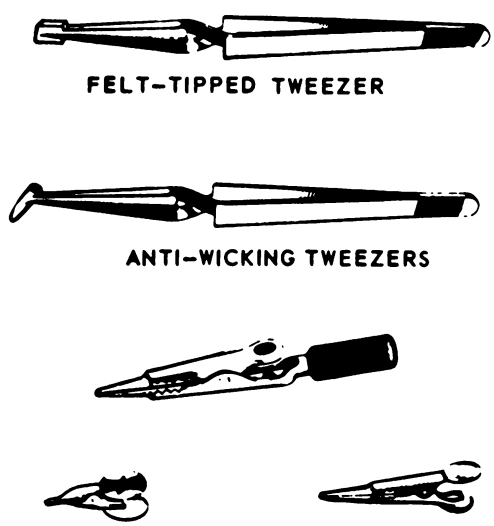

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Figure 7-5. Thermal shunts.

to be soldered. Clean the component leads before soldering. An efficient cleaning tool is shown in figure 7-6.

For cleaning soldered areas, use a medium-stiff natural or synthetic bristle brush or a lint-free, industrial cleaning tissue. Dip this into an approved cleaning solvent and use it to remove excess flux after the solder solidifies. You can use a pencil-style, white typewriter eraser for cleaning copper-clad unplated boards and for removing gold plating from printed-circuit pads and some component leads (refer to fig. 7-7). Avoid the use of knives, emery cloth, sandpaper, and other abrasives that can nick and scratch component parts.

Soldering Aids. Figure 7-8 illustrates three soldering aids that are useful in desoldering connections. Use the slotted ends to lift the ends of wire and component leads from the terminals. Use the pointed ends to remove solder from terminal holes and slots. You can use the bristle brush to remove molten solder, but you must be careful to keep from splattering the solder. Don't use wire brushes for this.

Don't use the soldering aids to exert force in security testing. A good visual inspection can determine the quality of a properly bonded solder connection. Bending or pulling wires to ascertain the security of the connection can present a serious reliability hazard and is acceptable only when a visual inspection is not possible.

Soldering Irons and Guns. The careful selection of an iron of the correct size, shape, and wattage is a prerequisite for reliable soldering. The size and shape of the iron and tip should permit soldering with maximum ease and with a minimum danger of damage to the surrounding area.

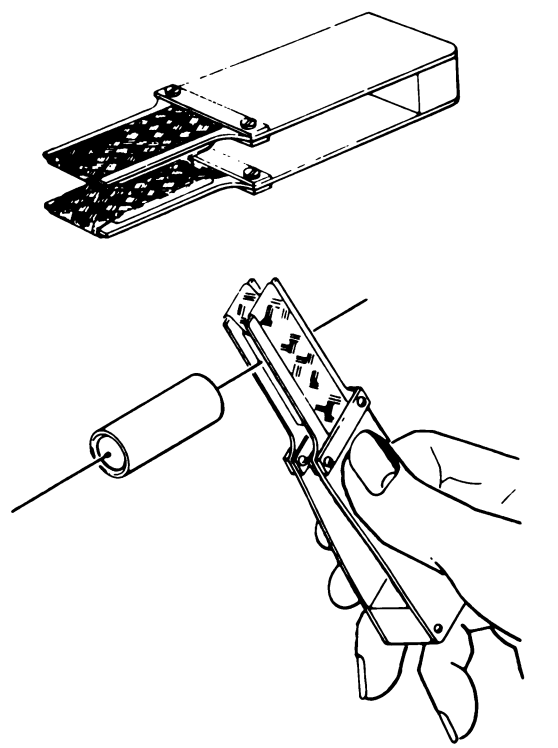

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Figure 7-6. Braided cleaning tool.

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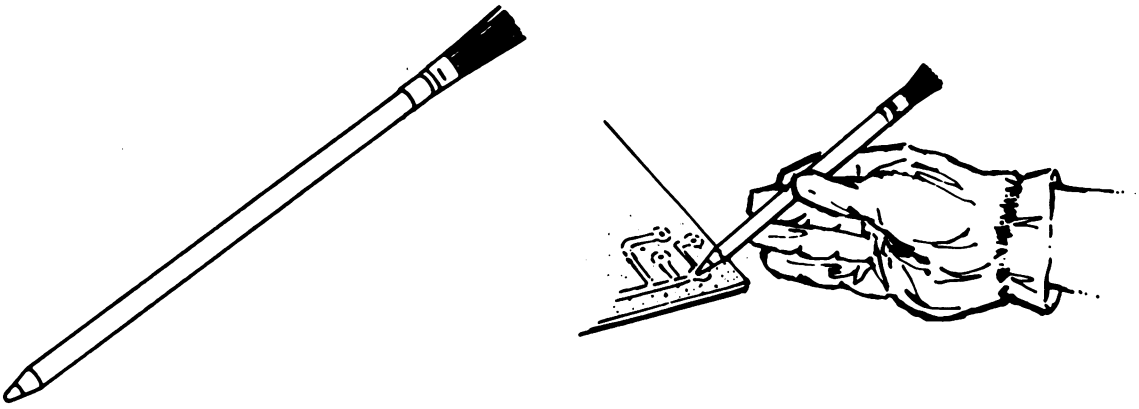

TYPICAL PENCIL-STYLE, TYPEWRITER ERASER

CLEANING OPERATION FOR PRINTED CIRCUIT PAD

NCS18-289

Figure 7-7. Typewriter eraser cleaning tool.

Soldering irons and guns are available in a variety of sizes and wattage ratings. Determine whether a soldering iron or a soldering gun is more suitable for the type of soldering operation to be done. Use a variable voltage supply to control the temperature of the iron when you solder printed circuits. A variable voltage supply also has advantages in many other soldering applications.

The size and shape of the connection being made determines, to a large extent, the wattage ratings of the iron or gun. Ratings of 25 watts to 100 watts are most commonly used in this career field. Ratings of 100 watts to 450 watts are generally used for soldering large terminals and metal chassis.

Exercises (046):

1. How may thermal strippers prevent the blistering or excessive melting of insulation?

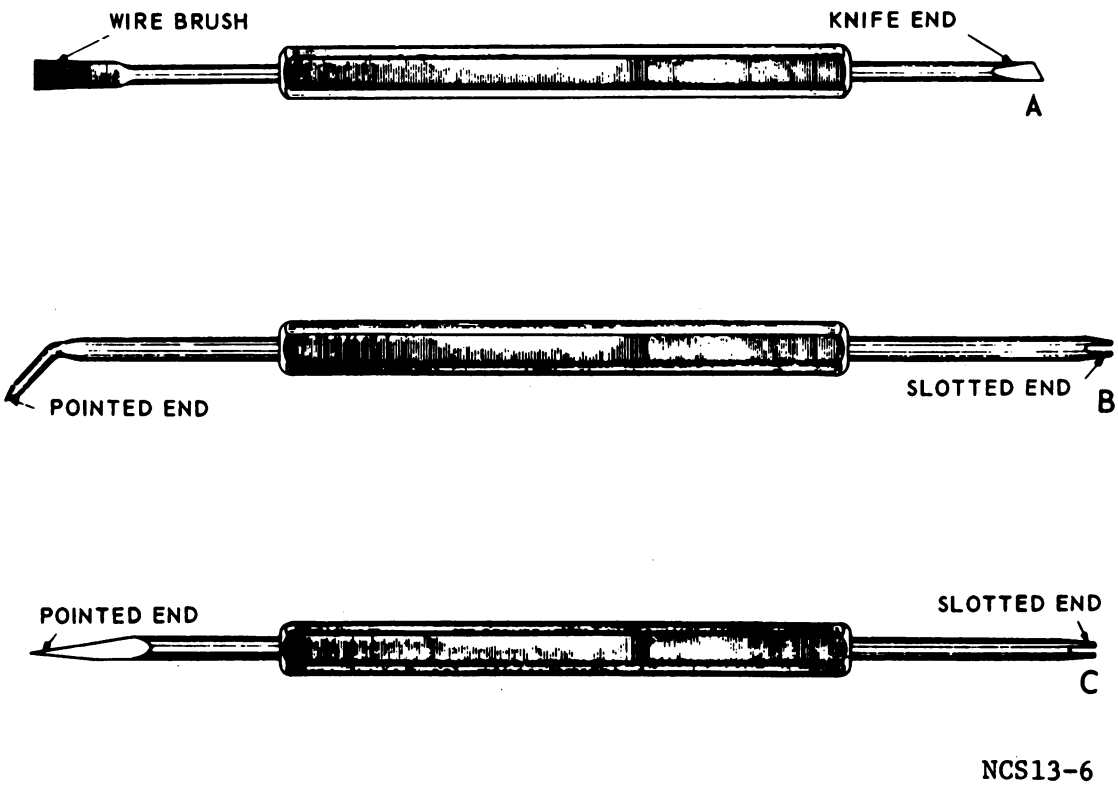

Figure 7-8. Soldering aids.

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2. State the proper use of bending tools.

3. What can you use to clean gold plating from printed-circuit pads?

4. Refer to figure 7-8, B and C. Explain the use of the slotted end of the soldering aids.

7-3. Safety

Always remember that a neat and orderly work area reduces confusion and contributes to safety and high-quality work. The safety of a work area depends primarily on the development and maintenance of safety practices by all personnel in the area.

047. Point out the advantages of a good safety program and some of the safety precautions to take during soldering operations.

Occasionally, good work may be turned out with poor tools in a poorly organized work area, but this is the exception. Using the wrong tool or failing to prepare your work area almost invariably increases the time you need to complete the job, the possibility of poor quality work, and your chances of being hurt.

In all areas, including those requiring special safety measures, there should be a lit of safety precautions containing the following items:

a. When soldering irons are not in use, place them in appropriate holders. This practice prevents the iron from burning the workbench or falling onto the floor. In either case, the iron is a fire and personal hazard, and the heating element of an electric soldering iron may be damaged by a fall.

b. Place the soldering iron where you don't have to reach across or around it. When you pick it up, always remember to look first at the soldering iron in order to avoid touching the barrel.

c. Do not test the heat of a soldering iron by holding it near your face. Test it with solder while holding it away from your body. You will avoid injury from sputtering particles of solder or flux.

d. Do not attempt to remove molten solder from a soldering iron by flipping. Use a rag, damp sponge, or canvas pad to wipe solder from the tip.

e. When you must carry a hot soldering iron, do not let the cord drag on the floor; it can catch on equipment and drag the iron through your hand.

f. Never use a file that is not fitted with the proper handle.

g. When unsoldering a wire, make certain there is no tension or spring in the wire. Wear safety glasses during this operation to keep hot solder out of your eyes.

h. When you are skinning or pulling wire with pliers, never pull toward your face. Under no circumstances use the pliers at eye level or in close proximity to your face.

i. When you are cutting wires, keep the open side of the cutter away from your body. Keep your wires in your own area, and prevent outside wires from entering your area.

j. To avoid electrical shock, disconnect all power and discharge the circuit before working on a chassis.

Exercises (047):

1. Describe the benefits of a well-organized work area and proper tools.

2. What is the recommended method of removing excess molten solder from a soldering iron?

3. If you are working on a chassis with power removed, why should you discharge the circuit before you make any soldered connections?

7-4. Soldering

Soldering is a physical skill that depends primarily on experience. No amount of written material can give you that experience. However, we can advise you on the general knowledge needed to perform the task.

048. Describe the chemical action that takes place during the soldering process.

Soldering Process. Before going into specific procedures about soldered connections, let's look briefly at the chemical action that takes place during the soldering process.

In its molten state, solder attaches by a metal solvent or an intermetallic solution action. We can illustrate the solvent or solution action with table salt. Ordinary table salt has to be heated to 1488° F. before it melts. However, when you add a little water to the salt, it melts easily without any heat. The action of molten solder on such a metal as copper can be compared to the action of water on salt. The solvent or intermetallic solution action chemically dissolves part of the metal surfaces to be joined at temperatures well below the melting point of the metals being soldered.

A soldered joint is chemical in character rather than purely physical because the attachment is formed in part by chemical action rather than by mere physical adhesion. Because of the solvent action, the properties of the soldered joint are different from those of the original solder, and you have a new and different alloy between the respective metals.

This new metal contact provides metal continuity while an unsoldered contact is discontinuous. When two metals are soldered together, they behave like one solid metal. In contrast, if they are bolted, wired, or otherwise only physically attached, they never make good electrical contact because of the insulating film on the surfaces of the metals.

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Exercises (048):

1. Describe the metallic solution action that takes place during a soldering operation.

2. Describe the advantage the soldered connection has over the wired or bolted connection.

049. Explain selected steps in the preparatory maintenance required for a soldering iron.

Making Soldering Connections. Research has shown that the best solder joints are produced within a narrow range of temperature and application time. Joint temperatures of 500° F. to 550° F. applied from 1 to 2 seconds produces the strongest connections. Therefore, you should select an iron with the size, wattage, and shape needed to provide these conditions. The iron tip should be able to heat the joint to soldering temperature rapidly. The amount of heat needed in the tip implies that the mass of the tip is large with respect to the mass of the metal being heated for solder application.

Still, the tip must not be so large that it obscures your vision or damages the adjacent parts or wire insulation. Also, the tip shape (such as spade, chisel, or pyramid) should be appropriate for the job you are doing. It is good practice to keep an assortment of spare tips and to change the tip as necessary to meet the requirements of various types of work.

As we stated earlier, the variable voltage soldering iron should be used on printed circuits, and it can be advantageous in many other soldering applications. By the proper selection of tips and voltage adjustments, you can use a single 50-watt pencil-type iron for soldering both miniature printed circuits and relatively large terminals. Thermostatically controlled irons require less skill in judging heat, but they are less versatile.

The unplated copper tip produces good results and is widely used in your career field. Because of pitting, burning, and oxidation, an unplated copper tip requires some preparatory maintenance before each use. The following is a brief description of the preparatory maintenance that may be required.

a. Insure that the tip is properly connected or screwed into the holder.
b. Clean off oxides.
c. Shape it properly for the task it will be used on.
d. Tin.

If any one of these items is not as it should be, preparation is needed:

a. If you have *armor clad* or *plated* tips, you can scale the oxides with an abrasive cloth.
b. You can form the copper tips into proper shape by filing.
c. Proper tinning procedures are as follows:

(1) Before heat is applied, clean the copper tip with a suitable file.
(2) Apply heat; after the minimum temperature to melt solder has been reached, apply solder to the dressed surface of the tip.
(3) Clean the tip by wiping it on a damp sponge or other soft material before you make each connection.

With the tip dressed and cleaned, you are ready to start soldering operations. Normally, this is simply a matter of applying heat and solder to a connection and then cleaning off the excess flux when the joint cools. At other times, you will be faced with the problem of unsoldering a joint, mounting parts or terminals, terminating shields, and repairing multiconductor cables. We will look at these in more detail later.

Exercises (049):

1. In selecting a soldering iron tip, what three conditions must you consider to make the best solder joint?

2. The mass of the tip should be _____ with respect to the mass of the metal being heated.
3. Explain the size restrictions you should consider in selecting a soldering iron tip.

4. Oxides may be removed from an iron or plated tip by _____
5. Describe the tinning process.

7-5. Desoldering

Since most of the soldering jobs in the Air Traffic Control career field are the removal, replacement, and repair of components, you must know desoldering techniques as well as soldering techniques.

050. Briefly outline and compare the basic desoldering techniques of wicking and sniffing.

Basic Desoldering Procedures. Although there are other techniques for desoldering, we will discuss only the *wicking* and *sniffing* techniques. Each of these techniques is very effective in removing the old solder from a previously soldered joint.

Wicking. Figure 7-9 shows some typical materials that can be used to make a wick. You can make an effective wick by stripping the braided shield from a piece of coaxial cable or by removing the insulation from a piece of multistrand wire.

This is the principle of wicking: if you apply heat to a well-saturated rosin wick, the solder will flow readily into the rosin area, leaving the terminal to which it was previously affixed. Almost as if by osmosis, the solder travels into the saturated wick.

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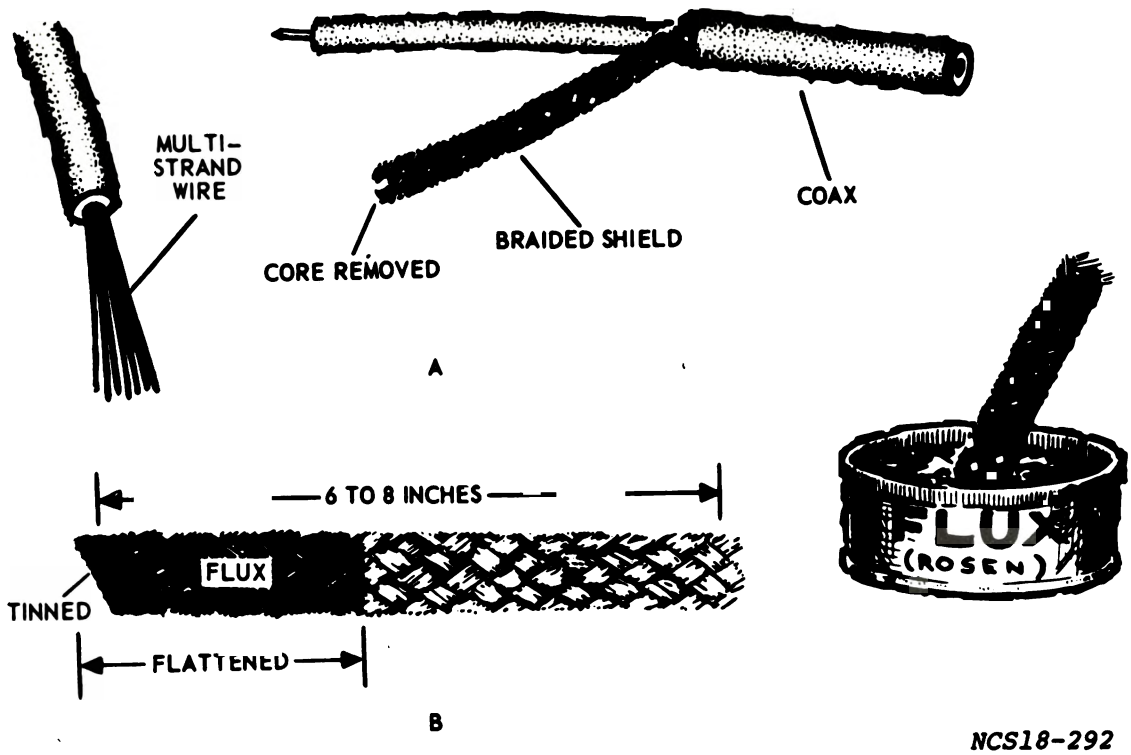

Figure 7-9. Wicking tools.

In preparing your wick, use a wire size no larger in diameter than the pad size that you will be wicking solder from. This is important because if you let the wick touch the board, it will "frogeye" the material on the board.

Refer to figure 7-9 A, and the list below for the procedures used in making an effective wick.

a. Remove 6 to 8 inches of shield from coaxial cable and flatten it with a bending tool.

b. Dip about 2 inches of the wick into liquid solder flux. Be sure the liquid flux rosin is the same as the rosin you intend to use in your repair work.

c. Tin the end of the wick by applying heat and a thin coat of solder.

d. If you use multistrand wire, strip about 4 inches of insulation from the wire.

e. Flatten the wire slightly, keeping the strands in place.

f. Dip the wire in liquid rosin and tin the end.

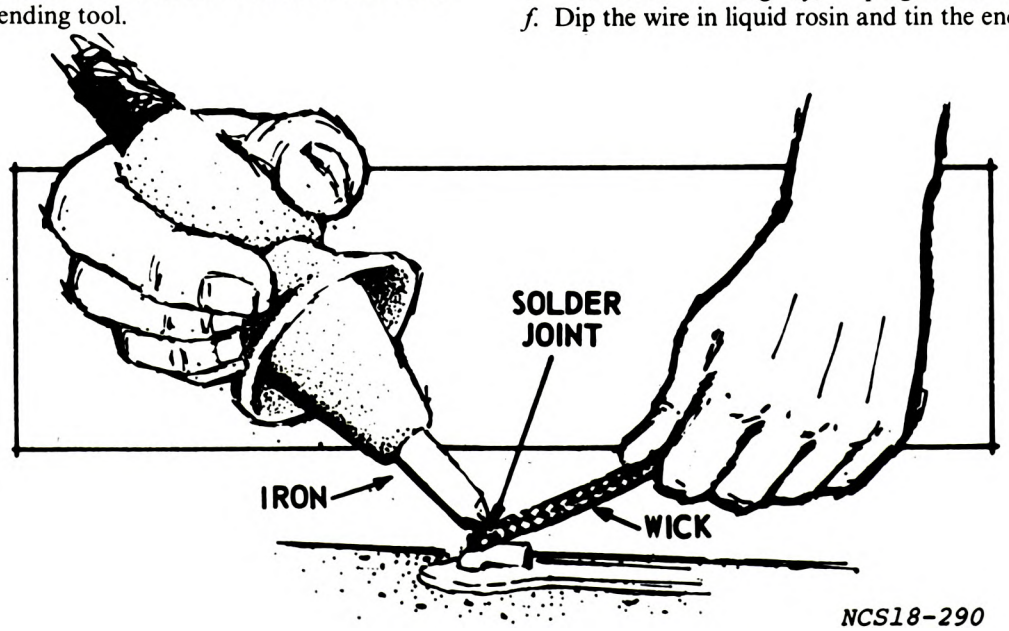

Figure 7-10. Wicking application.

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Now that you have an effective wick, let's see how to apply it, (refer to fig. 7-10).

a. Place the wick on top of the solder joint to be removed.
b. Place the iron tip on top of the wick. When the iron melts the solder, it will flow into the wick.
c. As the wick becomes saturated with solder, clip off the end of the wick, and repeat the operation until you have removed all the solder from the joint.

Sniffing. In this method, you use a tool like a syringe (refer to fig. 7-11). This tool is made from material that will not bond to solder. Although this method is not as highly recommended as wicking, it is effective.

The sniffer, or sometimes called "solder sucker," uses the force of air pressure to remove the molten solder. You use the sniffer as follows:

a. Squeeze the air out of the rubber ball at one end of the sniffer.
b. Keeping the ball depressed, place the pointed end of the sniffer next to the solder to be removed.
c. Heat the solder with a solder iron; keep the tip of the iron in the solder and *not* on the sniffer.
d. Slowly release the pressure on the sniffer ball. As the air enters the tube, it will pull the molten solder in with it.
e. After you have drawn the solder from the joint, remove the sniffer. Depress the tube again to remove the solder from the sniffer.

Each of these methods removes solder from a joint. In each method, you must exercise caution because of the heat, component reaction to heat, and possible damage to base materials and adjacent components.

Exercises (050):

1. Briefly explain the principle of "wicking."

2. Outline the steps involved in the "wicking" process.

3. Briefly explain the principle of "sniffing."

4. Of the two methods of solder removal, which is preferred?

7-6. Applications

Up until now, our discussion on soldering has been fairly general. Now, we will turn to some specific applications of soldering techniques.

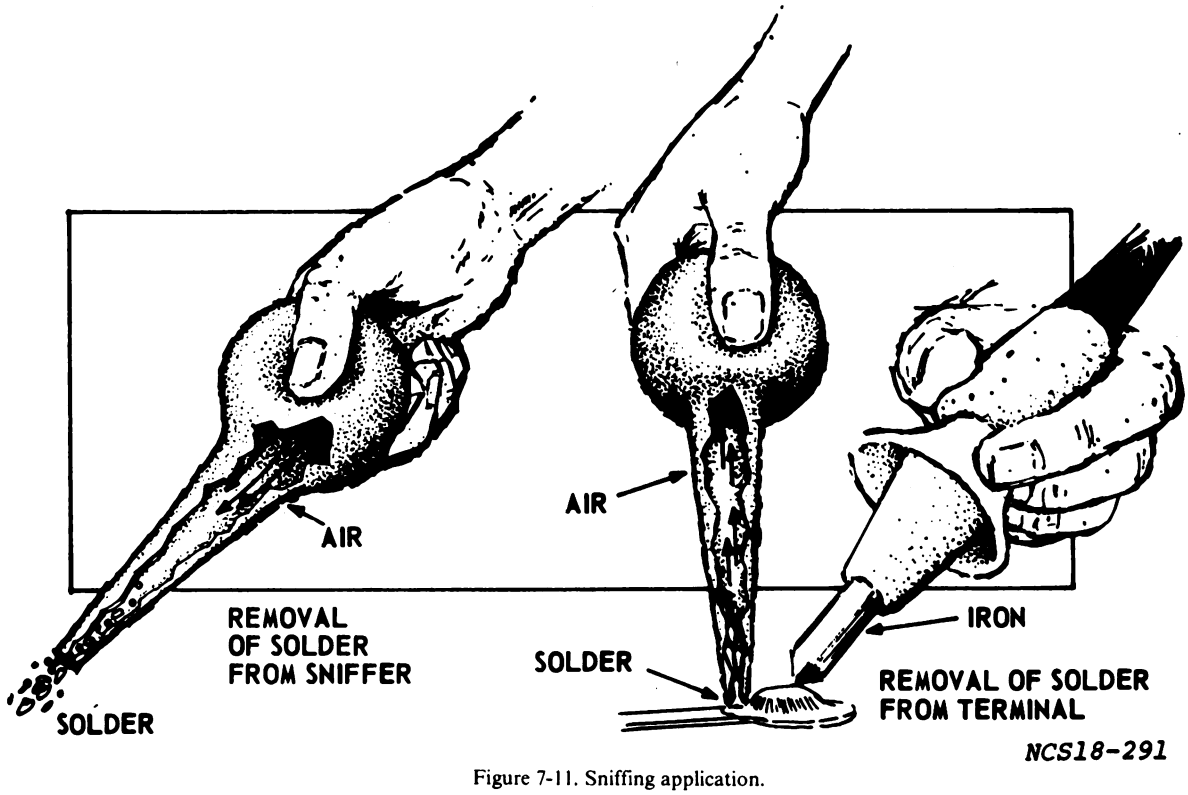

Figure 7-11. Sniffing application.

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051. Cite some of the procedures for preparing a wire or a component lead for a soldering operation.

Preparing Conductors and Part Leads. To strip insulation, you should use one of the specialized tools discussed earlier. If you are planning to strip many wires of the same size, we recommend that you tape over the unused holes in the precision wire stripper to avoid possible damage to the wire strands.

If you are using thermal strippers, be sure to remove the burned insulation residue. Remember, thermal strippers require ventilation. Inhaling the vapors from the breakdown of polymerized organic insulation can cause polymer fume fever.

If the stripping operation separates or discharges the strands, restore them to their original lay before tinning. If you nick the strands or damage the insulation, do not use the wire in a soldering operation.

Insulation gap. The end of the insulation should be far enough from the solder joint so that the insulation cannot become imbedded in the solder, but not far enough to permit a short circuit between two adjacent wires. In general, the length of the gap should be equal to approximately the wire's diameter, (see fig. 7-12).

Cleaning the part lead. To assure a good wetting action between the parts to be soldered, remove all impurities, such as dirt, grease, or oxide film. Also remove any surface contamination or corrosion formed during processing, storage, or handling.

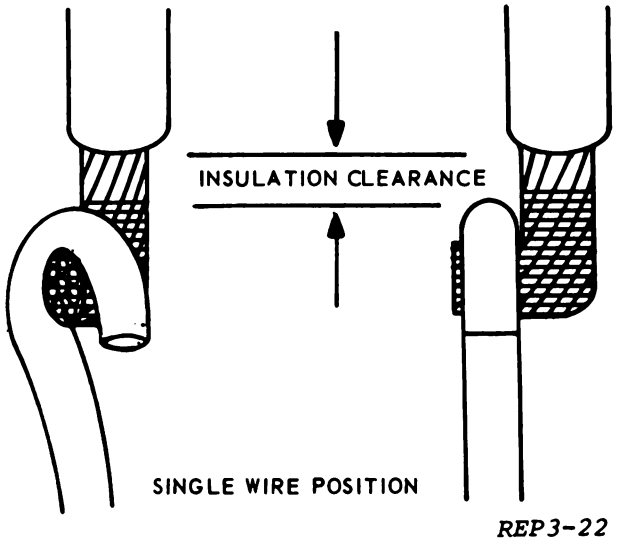
The tinning of the conductor wire should extend only far enough to take advantage of the deapth of the terminal or solder cup. Figure 7-13 illustrates the correct method for tinning. The solder applied during the tinning process should penetrate to the inner strands of a multistrand wire. If you tin the wire outside the terminal or solder cup where flexing may occur, it will cause stiffness and the wire could break.

Exercises (051):

1. How should a properly stripped multistrand wire look?

2. What is the normal length of a gap between the insulation and terminal?

3. Describe the recommended procedures for preparing a multistrand conductor for a soldering operation.



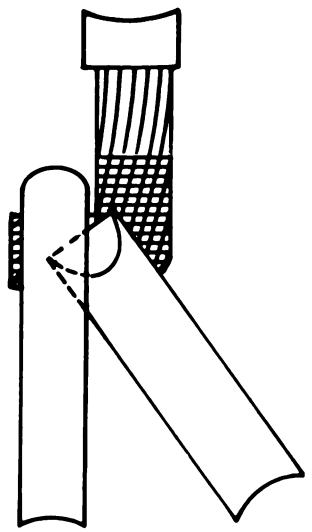


Figure 7-12. Proper insulation clearance for single wire position and soldering iron tip position.

052. Given a specific type of terminal, state the proper method for connecting a conductor to it.

Types of Terminals. The four most common terminals found in ATC radar equipment are bifurcated, turret, flat perforated, and hook. Let's briefly consider the proper method of connecting a conductor to these terminals.

Bifurcated terminal connections. The common methods of inserting conductors into a bifurcated terminal are called the bottom route and the side. If a top entry must be used, provide solder fillets to both prongs of the terminal.

For bottom entry, insert the tinned conductor into the terminal from the bottom, as shown in figure 7-14. Strip the conductor far enough so its insulation does not extend into the barrel (approximately 1/32-inch clearance is recom-

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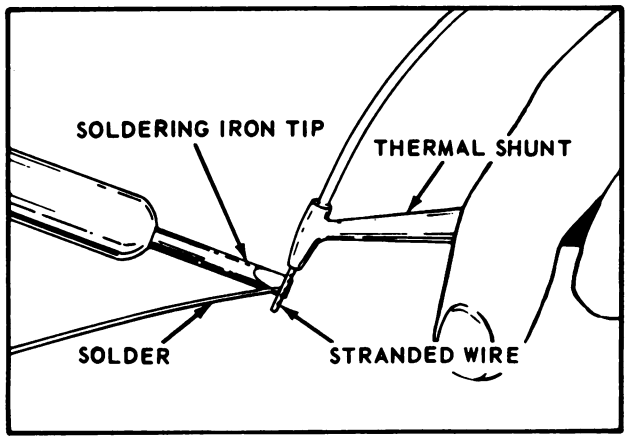

NCS13-8

Figure 7-13. Correct method for tinning wire.

mended). Bend the wire end to lie flush against the shoulder or one of the posts.

For a side entry, bring the tinned wire end through the gap and bend the wire flush against the post, as shown in figure 7-15, A. Bend a second wire in the other direction to lie flush against the other post, as shown in figure 7-15, B. Alternate additional wires in the same way. You may fill the gap, but under no circumstances should the last wire extend beyond the top of the posts. If the wires are smaller than 26 AWG, you may wrap them one-half turn around the posts if there is enough side clearance.

If the conductors must be inserted from the top, the wire should fill the space between the posts so that a fillet is formed to each post. A wire conductor of small diameter may be bent in a U-shape (fig. 7-16, B), provided the combined diameter is sufficient to fill the gap. A filler (solid or stranded) may also be used to fill the space, as shown in figure 7-16.

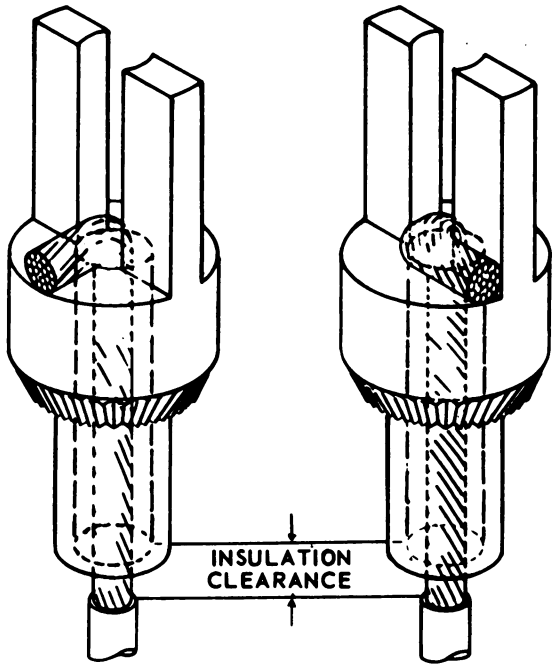

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Figure 7-14. Bottom route connection of bifurcated terminal.

Turret. Turret terminals (also called grooved and stud terminals) usually function as tie points for conductors and components in communications-electronics equipment. The terminals are normally divided into an upper grooved section and a lower grooved section. You should terminate your conductors on the lower section and the leads of small components (resistors, capacitors, etc.) on the upper section. Follow this arrangement, as far as practiceable, on turret terminals that have only one section rather than two.

In making wire connections on turret terminals, bend the tinned conductor into a loop of approximately one-half

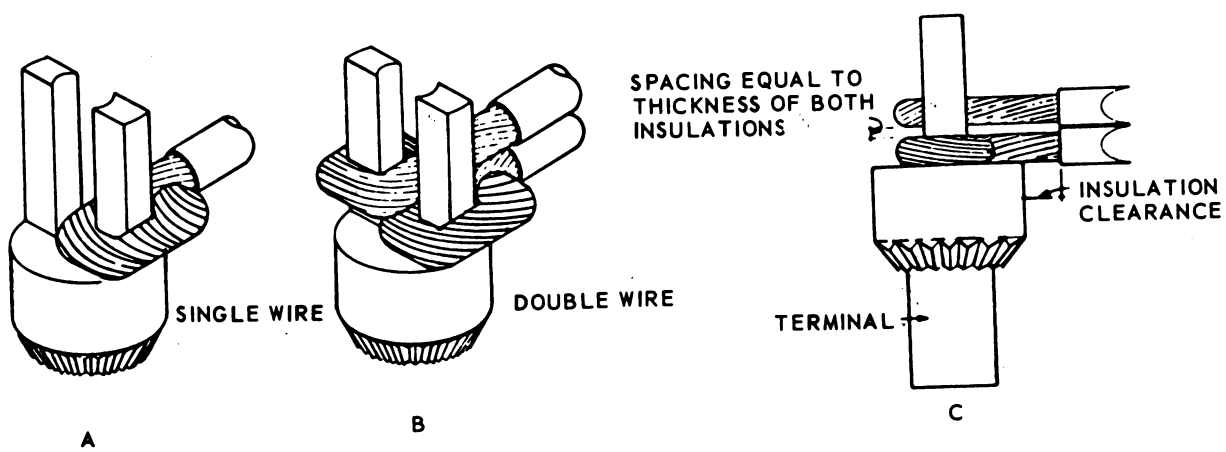

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Figure 7-15. Side route connection on bifurcated terminal.

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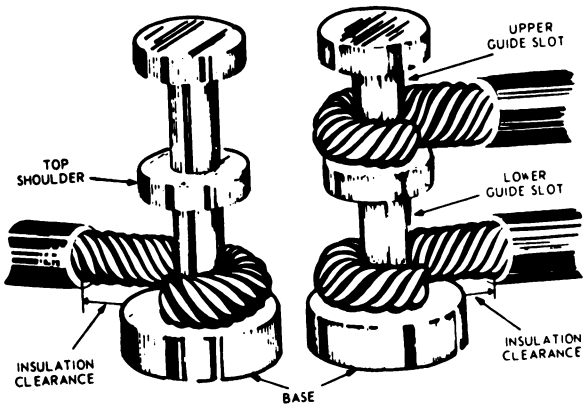


NCS13-17

Figure 7-16. Top route connection on bifurcated terminal.

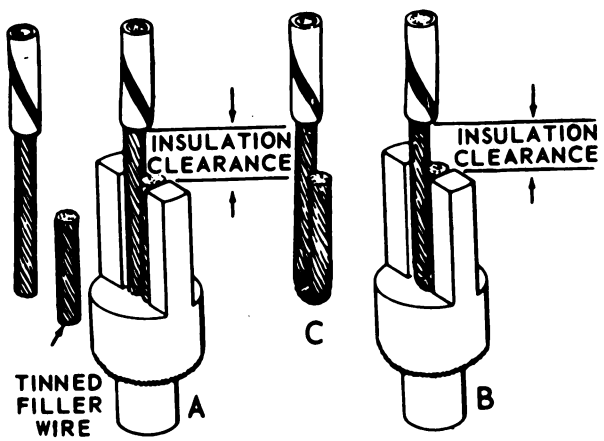
turn, slip it over the glide slot, and place it snug against the shoulder (see fig. 7-17). You may wrap wires smaller than 26 AWG to a full turn, but do not let them overlap. Do not wrap wires larger than AWG 26 more than three-fourths turn.

When you are using hollow-post turret terminals, insert the tinned end of the wire through the swagged end of the terminal, allowing 1/32-inch insulation clearance. Bring the tinned end of the conductor out of the side slot at the top and wrap it as required for the side route.

Flat perforated. Flat perforated terminals are flat metal strips of varying thicknesses and lengths with a hole through one end to accept conductors and the other end mechanically connected to equipment components. Some of the more common applications for this type terminal are as connecting points for tube sockets, jacks, and signal lamps.

When attaching wires to perforated terminals, use a minimum of one full wrap and a maximum of 1½ wraps. Figure 7-18A, illustrates a 1½ wrap. If space is insufficient, as with most miniature tube sockets, make a mechanical connection by feeding the wire through the terminal hole, using a 180° wrap (fig. 7-18B) and then firmly crimp the wire.

Hook and eyelet. This type of terminal is most often found on relays and lamp bases. When attaching wires to the hook or eyelet terminal, you should wrap them around the terminal a minimum of one-half of a turn and a maximum of three-fourths of a turn. Figure 7-19 illustrates single-wire and double-wire connections on a hook terminal.



NCS13-20

Figure 7-17. Turret terminal connections.

Exercises (052):

1. Give the correct procedure for making a fillet for a top entry connection on a bifurcated terminal.

2. What is the recommended insulation clearance on the bifurcated terminal?

3. On which section of the turret terminal should your conductors be terminated?

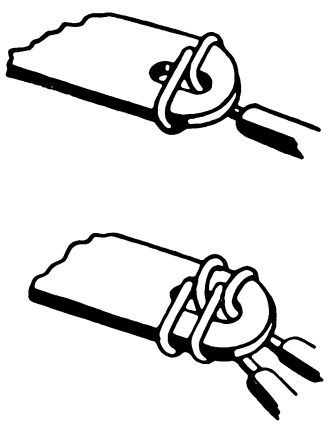


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Figure 7-18A. Correct wrap for flat perforated terminal.

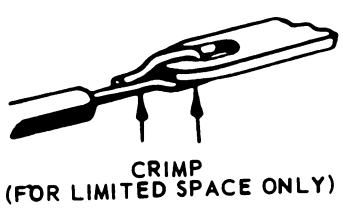

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Figure 7-18B. Crimp (for limited space only).

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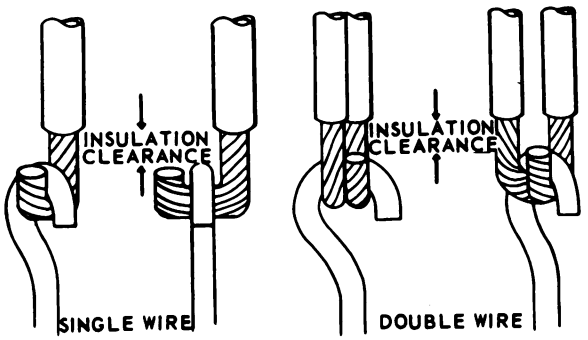

Figure 7-19. Hook terminal connections.

4. Describe the method for connecting conducts to flat perforated terminals if clearance is limited.

7-7. Soldering Printed Circuits and Microelectronic Circuits

Because of their increased reliability, economical operation, increased packing density, and reduced weight, printed circuits and microelectronic circuits are used in electronic equipment in an ever-increasing number.

053. Describe selected precautions associated with printed-circuit assembly repair.

General Precautions. Certain precautions are necessary in soldering printed-circuit boards because of the delicate nature of the wiring material and wiring-to-board bonding and the heat sensitivity of the miniaturized parts. When you solder printed-circuit boards, observe these general precautions:

a. To reduce the amount of heat required for the soldering operation, use a solder of smaller diameter (1/32-inch maximum) and low-melting point.

b. Use a 50-watt iron or less.

c. Use grounded soldering iron equiment or ground the soldering iron tip, preferably with alligator clip leads. (The leakage current of some soldering irons is enough to damage transistors and small semiconductor devices.)

d. Use enough thermal shunts to protect heat-sensitive devices sufficiently.

e. Make sure that the total time of heat application does not exceed the time required to melt the solder and properly fuse the solder with the terminal pad and component lead. When you make a solder connection, apply the smallest amount of heat needed to produce a satisfactory connection.

f. If you have trouble soldering a connection, stop and let the connection cool completely before you attempt to resolder.

g. Remove flux and flux residues from the solder connections within 90 minutes after the completed connection has cooled. (Remove them with isopropyl alcohol or aliphatic naphtha.)

Exercises (053):

1. What is the maximum diameter recommended for the solder used in printed-circuit repair?

2. Why should the soldering iron tip be grounded during the repair of printed-circuit boards.

3. Describe the proper procedure to follow if you have difficulty in soldering a connection.

054. Name the two types of part lead terminations and compare their uses.

Part Lead Terminations. Part leads are terminated on printed-circuit pads using clinched leads (standard) or unclinched leads (special).

For a clinched lead termination (fig. 7-20), the part lead extends through the printed-circuit board for a maximum of the printed-circuit pad's radius and a maximum of the pad's diameter. The part leads are clinched in the direction of, and parallel to, the printed-circuit wiring pattern. The clinched lead should contact the printed-circuit pad; however, an angle between the clinched lead and the printed-circuit pad of up to 30° is acceptable.

The unclinched lead termination (fig. 7-21) is used in special cases where parts are light and there is no stress on the solder connection. For this termination, the part lead should extend through the circuit board for a maximum distance of 1/32 inch. Normally, all parts using the unclinched termination are rigidly secured to the printed-circuit board by suitable mounting clamps or an epoxy-resin compound.

Satisfactory solder connections for clinched and unclinched lead connections and for clinched and unclinched lead terminations have the following characteristics:

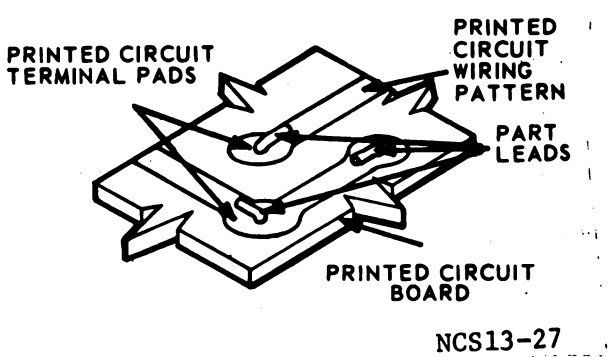

Figure 7-20. Clinched lead terminal.

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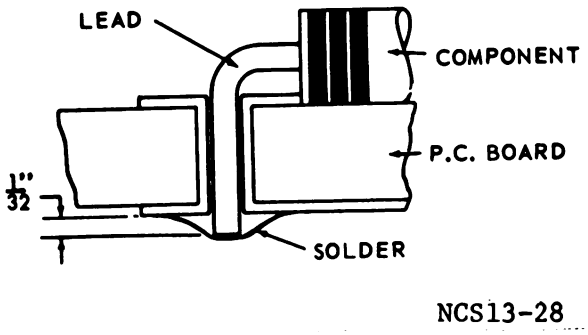

Figure 7-21. Unclinched lead termination.

a. The contour of the part lead is visible.

b. A concave fillet is formed between the part lead and the terminal pad.

c. The concave fillet blends into the completely wetted (solder fused smoothly into all portions) terminal pad.

d. The solder is smooth and shiny and has no voids or gaps.

e. The color of the rosin residue from heated flux is from light amber to a medium brown after the solder operation. (This rosin residue must be completely removed after the connection has cooled.)

Exercises (054):

1. Name the two types of lead terminations recommended for printed circuits.

2. How does the use of the second lead termination differ from the use of the first type?

055. Given specific circuit-board repair problems, name the proper procedure for each.

Repair. Before you begin to repair printed circuits, read the system's technical orders to learn the degree of maintenance authorized on your printed-circuit boards. Also determine whether there are any quality control directives governing the methods of repair. Here are some of the most common discrepancies and repair procedures connected with printed-circuit boards.

Repairing damaged strips. If, during troubleshooting, you find a break in the conducting strip in a printed-circuit board, you or your supervisor must determine what course of action to take. Whether you repair or replace the printed-circuit board depends upon the amount of damage to the board and the level of maintenance authorized in your organization.

Generally, if the break in the conducting strip is small, you should lightly scrape away any coating covering the conductive strip to be repaired. If possible, clean the area with a pencil-style typewriter eraser, or you can use a firm bristle brush (not a wire brush) and an approved cleaning solvent. Repair the broken area of the foil by flowing solder over the break as shown in figure 7-22, A. If there is any indication that the strip may peel or if the break is larger than a crack, bridge the area with a section of bare wire, as shown in figure 7-22, B, and apply solder along the entire length of the wire to bond it solidly to the conducting strip. Keep the solder within the limits of the strip that you are repairing.

If the conducting strip is burned out or fused, cut and remove the damaged strip. Then connect an insulated wire across the break and solder. (See fig. 7-22, C.) If the strip terminal is removed, instead of soldering to the strip, as in figure 7-22, C, use an insulated standoff at the damaged terminal or replace the whole strip with a conductor strip from a printed-circuit board repair kit. Repair kits contain

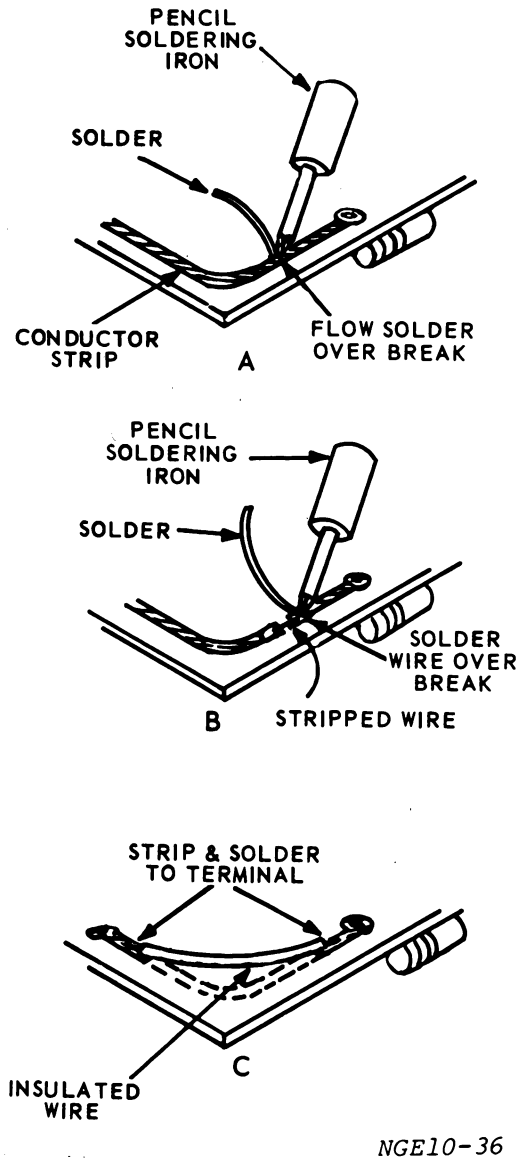

Figure 7-22. Methods of repairing broken conducting strips.

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instructions for the replacement of printed-circuit board conductor strips.

Component replacement. The job of removing and replacing defective components on a printed-circuit board is not difficult, but it does require a certain amount of care because of the fragile construction of the board. The misuse of a soldering iron or the use of improper handtools can be result in the complete replacement of a printed-circuit board instead of merely a component on the board.

The tools used to repair metal chassis are not practical in the repair of printed circuits. Many different tools are used for special jobs, but only those most frequently used are given below:

a. Printed-circuit board vise.
b. Heat sinks.
c. Longnose pliers.
d. Soldering aids.
e. A 20- to 40-watt soldering iron.
f. Assorted soldering tips.
g. Stiff bristle brush.
h. 60:40 solder—63:37 solder preferred for solid-state and microminiature circuits.
i. Wiping cloth or sponge.
j. Rosin paste.

The usual steps in the removal and replacement of a defective component are listed below. Remember that these are general steps and in certain instances will not apply to your particular situation.

Secure the printed-circuit board in a repair vise before you do any work on it. With the board in the vise, you are ready to begin removing the defective components. Grasp the lead on the end of the component with longnose pliers. If you are not sure that the component is defective, place a heat sink as near as possible to the body of the component.

Apply the soldering iron to the component lead (37-watt soldering iron recommended), being careful not to touch the eyelet through which the lead is soldered. When the solder within the eyelet begins to flow, gently pull the lead through the eyelet with the longnose pliers. Repeat this procedure on the other component lead. Clean both eyelets before the new component is installed.

After cleaning the eyelets on the board, you should be ready to install the replacement. If you have not previously shaped the leads of the new component, do so now. Insert the component lead through the eyelet, and hold it in place with a pair of longnose pliers. Remember, use a heat sink if your component is affected by heat. With the lead in place, apply a soldering iron to the component lead and allow solder to flow into the eyelet. Then repeat the procedure on the other lead.

After soldering the component, inspect your work for any defects. Listed below are some checks that will help you. As you become more proficient in the maintenance of printed-circuit boards, you will be able to add to this inspection list:

- Check the component for security.
- Check the solder bead—it should be shiny and smooth.
- Check the printed wiring (foil). The heat of your iron may have separated the printed wiring from the board.

Exercises (055):

1. What procedure should you use to repair a small break in the conducting strip of a printed circuit?

2. What should you do if the conducting strip shows signs of peeling?

3. What is the first thing you should do before replacing parts on a printed-circuit board?

056. Describe the emergency repair of a printed-circuit board.

Emergency Repair. In many instances, you must use timesaving techniques and procedures in the emergency repair of electronic components. In an emergency, it is desirable to avoid disassembling the unit more than is absolutely necessary to expose the defective part for both testing and repair. You can often do this by merely removing the cover of the assembly.

There are numerous methods of emergency repair and the repair situation can vary widely as a result of the malfunction. We obviously cannot present all methods here. Therefore, we will limit our discussion to just one example of emergency repair. The following steps show you how to remove and replace a defective component by using its leads.

After you have found the defective component in the printed-circuit board, cut its leads as close as possible to its body and remove it (see fig. 7-23, A). Straighten and clean the leads remaining on the board from the removed component. Obtain a replacement component and fashion a small loop at both ends. (Refer to fig. 7-23, B.) Make the loops so that the new part can slip easily over the defective component's leads. Secure the connections by bending the old leads away from the part, as shown in figure 7-23, C. Place a heat sink clamp on the lead from the board to prevent that lead from becoming unsoldered. Solder the lead and the component together (see fig. 7-23, C.) Make sure that the old leads have not been disconnected from the circuit board during the soldering operation.

Exercises (056):

1. Where should you cut the leads on the defective part during emergency repairs on a printed-circuit board?

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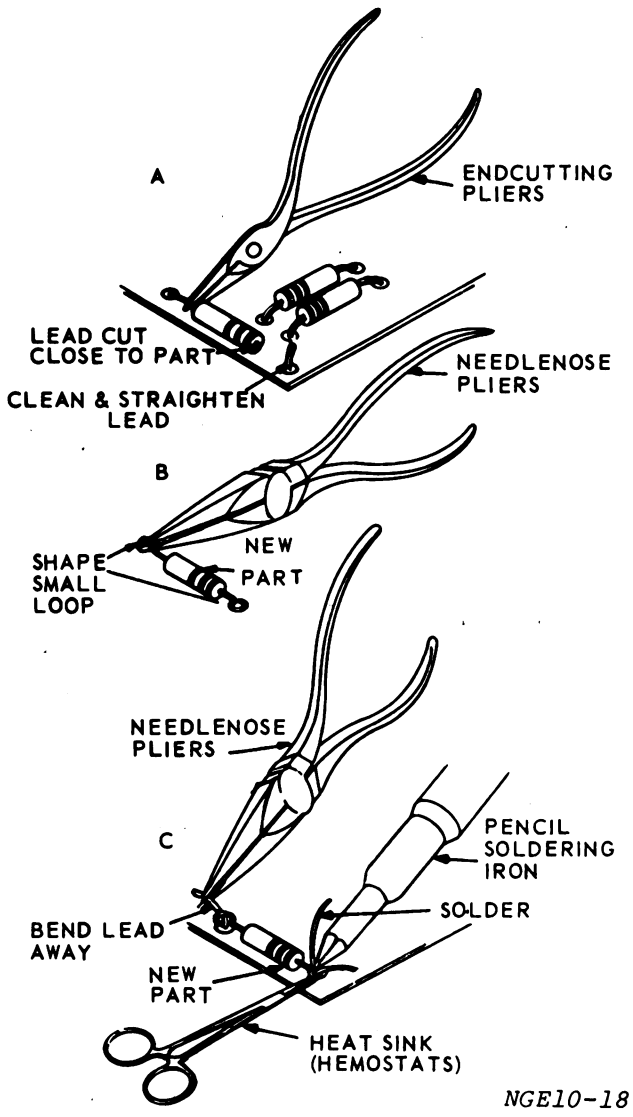

Figure 7-23. Emergency repair.

2. Briefly describe the procedure for installing a new component using the emergency repair method.

052. State the procedures for preparing and installing an integrated circuit on a printed-circuit board.

Installing Microelectronic Integrated Circuits. Microelectronic integrated circuits are miniaturized devices containing elements fused together to form passive or active electronic circuits. These circuits are potted or hermetically sealed in small packages. Like the transistor when it was first introduced, these circuits caused some confusion until procedures for their installation, testing, and replacement were established.

If properly installed, the microelectronic device withstands a great deal of abuse and vibration, but the best engineered device in the world is no better than the solder joint that connects it into the electronic circuit.

In maintenance work, you must treat a package of microcircuits as you would any other discrete component, exercising, of course, the kind of care in handling that these packages require. The usual packages for microelectronic circuits are: (1) a TO package (fig. 7-24, A); (2) a flat pack (fig. 7-24, B); and (3) a standup flat pack (fig. 7-24, C). Many different techniques are used to secure these devices to a printed-circuit (PC) board, such as gap welding, resistive soldering, thermal agitation, electron beam bonding, reflow bonding, and the lapflo system. (The lapflo system is discussed later in this chapter).

TO Packages. There are several different types of packages used for encasing microcircuits. The TO package shown in figure 7-24, A, is the most widely used. This type of packaging should be familiar to you because of its extensive use as a case for transistors. However, as a result of modern-day technology, the content of the package is quite different from the transistor. Inclosed are the many components used to make monolithic-integrated circuits, multichip circuits, and hybrid-integrated circuits.

Component preparation. Most component leads are gold plated during the manufacturing process to prevent their oxidation. If the leads are gold plated, you must remove the plating from the leads with a white, pencil-style typing eraser or other specialized cleaner before you make any attempt to solder them. If the leads are not plated, use the typing eraser or a component lead cleaner to remove the oxidation.

Circuit-board preparation. Printed-circuit boards should be thoroughly cleaned and prepared for component installation. Different boards and their methods of preparation are described below:

a. Tinned lead-plated boards are the easiest to prepare. All you need to do is clean them thoroughly with a medium-bristle brush and alcohol, and then wipe them dry with a lint-free cloth or tissue. Be sure that each hole and pad is free of foreign matter.

b. Clean copper-clad unplated boards with a white, pencil-style typewriter eraser. The pad is clean when the whole pad shows a bright uniform appearance. Follow this cleaning with the brush and alcohol cleaning treatment.

c. Gold-plated boards are the most difficult to prepare because the gold plating must be removed from all areas to be soldered. Remove the plating with the white, pencil-style typewriter eraser. A uniform gold-pink color all over the pad is the required condition. Again, follow this with brush and alcohol cleaning.

Component mounting. A component can be mounted on the PC board in a variety of ways. The two most common methods are flush mounting and imbedded can. In the imbedded-can method, you mill out the PC board to set the package into the recessed slot bottom up. This type of mounting is the most desirable because it permits the use of a heat sink.

For clinched lead termination, first insert the component on the board. Using a pair of flush-cutting pliers, cut the leads to the proper length. The minimum length is the pad

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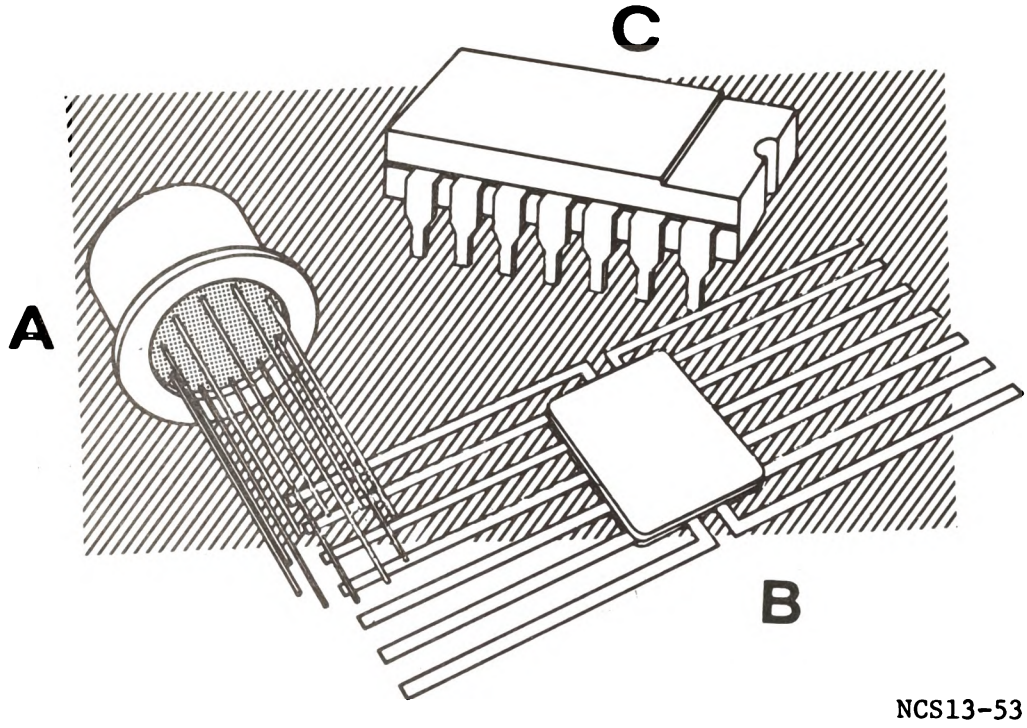

Figure 7-24. Microelectronic packages.

radius and the maximum length is the pad diameter. Using a lead-forming tool, force the leads over in the direction of the PC board conductor run until they are flush with the board.

On special mountings where a round pad is used, the lead is not clinched. It comes straight through the board for a distance equal to the width of AWG 20 wire. Hold a piece of AWG 20 bus wire next to the lead and cut the lead flush with the wire.

After the component lead is properly formed, cut, and clinched to the board, clean the connection once again with the cleaning brush and alcohol. Do all soldering on the board with the board flat on the cleaning pad. If you must use a heat sink on a heat-sensitive component, place the board in a PC board holder.

Clean the tinned soldering iron tip by wiping it lightly with a wet sponge. It is important that the iron tip be free of old solder because old solder does not mix with new solder.

A good temperature for most joints is one that is hot enough to melt the solder readily and heat the joint without damaging the board or component. In most cases, micro-miniature packages are soldered into the circuit with a 17-watt iron and a variable voltage source setting of approximately 100 volts. For larger pad connections with less-sensitive components, a standard 37-watt iron is desirable.

While you must keep the application of heat to a minimum when you connect micropackages to PC boards, enough heat must be transferred to the surface to insure a reliable connection. One method of insuring sufficient heat quickly is to use a heat bridge. A heat bridge is formed when the soldering iron tip and the component lead are bridged with a small diameter, low-melting-point solder. Place the iron tip flat against the side of the component lead and center it on the pad, as shown in figure 7-25. Form a heat bridge at point B. Move the solder down the lead (in the direction indicated in fig. 7-25) to the wire end. Tin the cut end and then move around the pad back to the soldering iron. Remove the iron and solder. After the joint is cool, clean it thoroughly with a brush or tissue dipped in alcohol.

To replace a component, wick off all solder on all joints and remove the component. Prepare the PC board and install the new component, using the procedures outlined in the above paragraphs.

Exercises (057):

1. Give the procedures for preparing a copper-clad unplated board for a soldering operation.

2. Describe the appearance of a gold-plated board that has been properly prepared for a soldering operation.

3. State the procedures used in the heat-bridge method of soldering.

7-8. The PACE Electronic Maintenance System

This section deals with the PACE electronic maintenance system. Many of you have probably already seen a PACE station being used in your work center. This equipment

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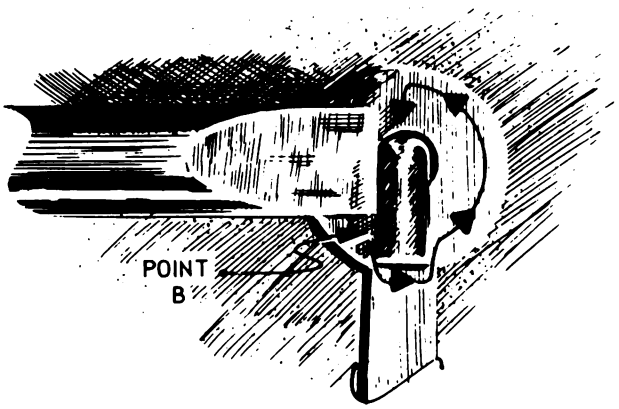

Figure 7-25. Soldering operation.

provides a maintenance section with the ability to restore electronic equipment to its original quality and reliability standards. The PACE system is comprised of a power source and a number of functional accessories that combine to accomplish the high-reliability soldering and repair work necessary today.

Please note that although the information contained in these objectives was extracted with permission from the PACE Manual for Electronic Maintenance System, Model PRC—350C, we strongly recommend that you read the instruction manual provided with your system before using it.

058. Differentiate between the purposes of the power source's elements and describe their use in the setup and operation of the PACE system.

Power Source. The power source is the heart of the PACE system. It provides all of the following functions: air pressure, vacuum, mechanical power, an infinitely variable low level of AC and DC power, and finally, two levels of fixed and three levels of variable AC power. These capabilities can be used to accomplish almost any electronic repair or soldering operation. Figure 7-26 shows many of the controls located on the power source and the following text outlines their setup and use.

a. Before applying power, all switches and control knobs should be placed in the OFF or "O" position.

b. Connect the power cord (22, fig. 7-26) to a properly grounded outlet.

c. Turn the main power switch (1) ON. The red main indicator (2) should be lit and the fixed AC line receptacle (10) should be hot. Also, variable AC receptacles (8, 9, and 21) can now be activated and controlled by controls (6, 7, and 16).

d. For many of the functional accessories provided with this system the mode selector (3) will provide the mechanical and/or primary electrical power needed. The two-position foot pedal (23) allows foot control over the power supplied to the accessories. The various combination of motor (M) and primary electrical power (E) provided are listed below:

Position 1. E—Foot pedal activation provides primary electrical power to both the AC and DC outlets (12 and 13). Output control (15) controls the output level of these low-power signals. The exact level of DC output can be monitored with the DC volt readout (17).

Position 2. M—Provides power to the minichine (11) and allows either pressure (4) or vacuum (5) to be activated by the foot pedal.

Position 3. E/EM—The first position of the foot pedal will provide power to the primary electrical AC and

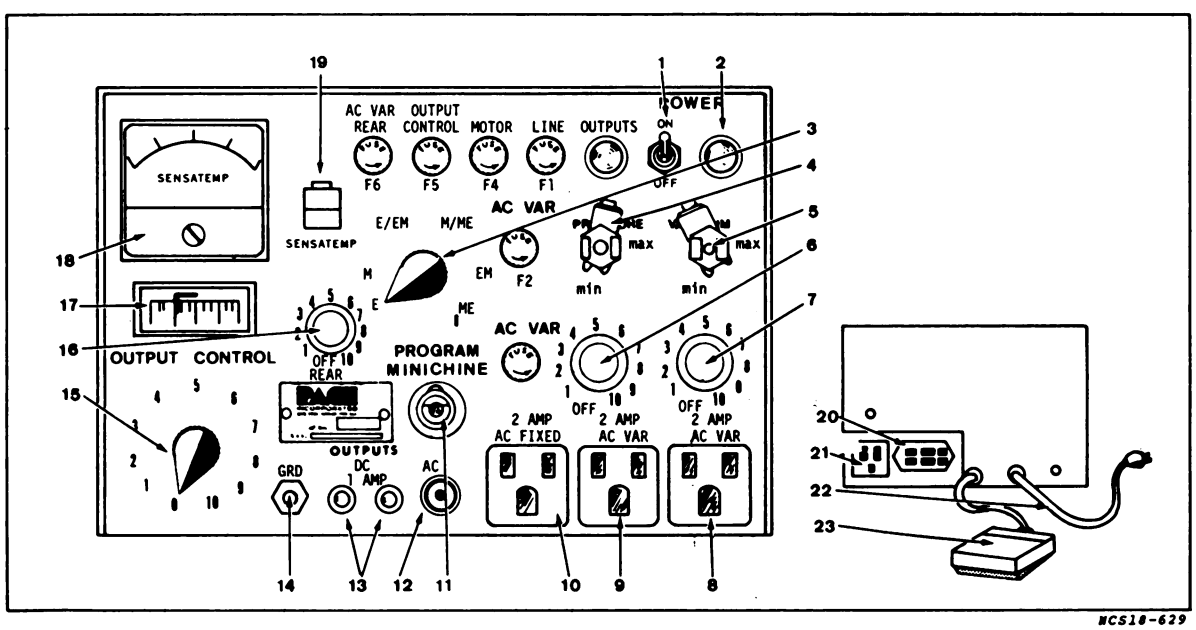

Figure 7-26. Power source.

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DC outputs. The second position of the foot pedal provides both primary electrical and motor outputs.

Position 4. M/ME—In this mode, the motor is activated in the first foot pedal position, and both the motor and primary electrical power outputs are again provided in the second.

Position 5. E/M—The first position of the foot pedal will activate only primary electrical power and the second will activate only the motor.

Position 6. M/E—The reverse of the previous position.

e. The ground terminal (14) should be used as required to protect a workpiece (the component being worked on) from stray current flow.

f. When the motor is activated, mechanical power is provided to the minichine (11) in one of two modes, *idle* or *quick-connect while running.* Please consult your operating manual for specific guidance on how to use these modes.

g. Pressure and vacuum flow rates are variable from minimum to maximum as shown on their controls (4 and 5). The maximum pressure and vacuum flow rates are factory set but can be reduced by loosening the ball caps on the controls.

CAUTION: Presented here and throughout this section are many precautions that should be taken. When you use the low-voltage AC or DC outputs, remember that their usage is based upon a 50-percent duty cycle; i.e., for each 5-second period power is applied, there should be a 5-second period that power is OFF. Accessories such as the tungsten or carbon-type resistive heating elements are especially susceptible to degradation if not provided this cooling-off period. Items exempt from this standard are: the miniature soldering units, thermal parting unit, and the thermal stripping unit. Except for these exempted items, no accessory using this low-voltage AC or DC output should be used for more than a 10-second continuous period. Again, please consult the operating manual for specific guidance on each accessory.

As you know, *heat* is required for all soldering and desoldering operations, but the application of too much heat will damage many of today's electronic circuits. You should use only enough heat to reach the solder's melting point. This is necessary to prevent damage to the electronic circuits. Remember many of today's bonding and coating materials have a melting point that is only slightly higher than the melting point of solder. Precise temperature control is provided over all conductive heating elements used with the PACE system by using the SensaTemp(TM) and its adjacent temperature readout (18 and 19, fig. 7-26).

To use this device, place the heated component against the SensaTemp and read its temperature on the scale. The specific temperature required to reach the melting point of your solder is achieved by varying the voltage applied to the component. Remember that earlier in this chapter, we discussed the solder melting point of various eutectic combinations. As a general rule, if the type of solder is not known, start at a temperature of 350° F.

Exercises (058):

1. In mode M, what functions are available from the PACE power source?

2. When should the ground terminal be used?

3. Which devices are very prone to heat damage if not given a cooling-off period?

4. How much heat should be applied to a component that is to be soldered or desoldered?

059. State the purpose and proper use of the functional accessories used with the PACE power source.

Functional Accessories. It is the functional accessories that transform the capabilities of the power source into a working output. An explanation will be provided for the function and purpose of each of the following accessories; environmental probe, SODR-X-TRACTOR unit, minichine system, thermal stripper, resistweez unit, thermopart system, lapflo system, and the conductweez device.

Environmental probe. Figure 7-27 shows the components that make up the environmental probe. This unit provides a variable hot air output that can be used for the rapid drying of localized areas, for accelerating the curing process of coating and bonding materials, and for troubleshooting.

The probe is connected to the *Fixed AC* output and the *Pressure* side of the power source. Initially you should apply power for a period of about 30 to 45 seconds. Then, with power still applied, turn on the air supply and allow the probe to stabilize for approximately 2 to 3 minutes before using.

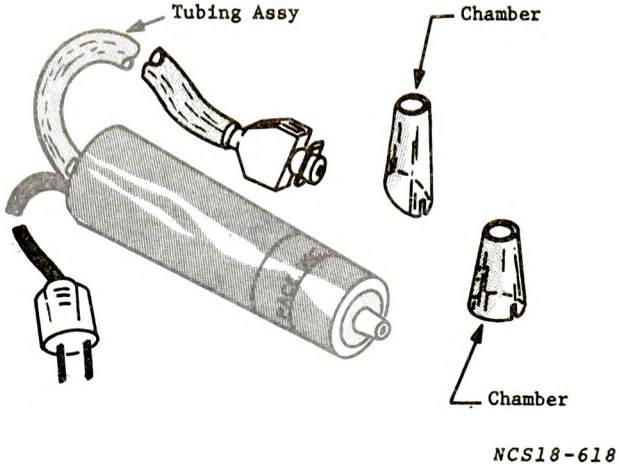

Figure 7-27. Environmental probe.

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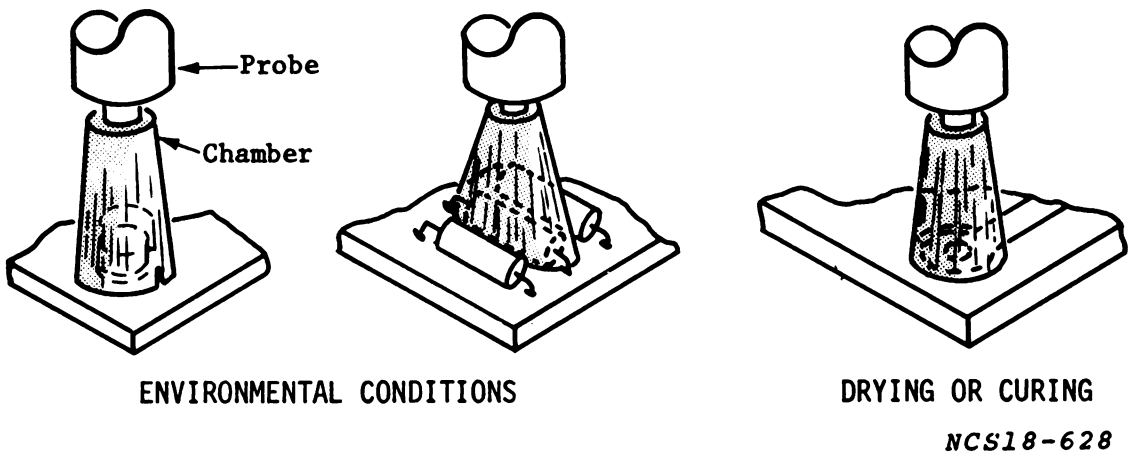

Figure 7-28. Environmental probe uses.

When you use the probe for fault isolation (heating or cooling an individual component to induce breakdown) first select the proper chamber to fit over the workpiece (i.e., either the round or slightly flattened unit) and then assemble the chamber with the probe, as shown in figure 7-28. Do not try to force the chamber over the workpiece, but rather form it to fit so that it makes a seal with the surface that the workpiece is located on. When the probe is used for drying or curing, localized temperature accuracy is not critical. You may use either of the probe chambers or one of the tips furnished with the vacuum tweezer unit.

SODR-X-TRACTOR. The SODR-X-TRACTOR, shown in figure 7-29, functions as a vacuum cleaning device for solder removal. In operation, the heated X-TRACTOR tip quickly melts the solder. Then, with the power source in the motor mode, depressing the foot pedal generates sufficient vacuum pressure to transfer the melted solder from the circuit to the safety chamber in the SODR-X-TRACTOR handle. To prevent blockage of the heater chamber, insure that you maintain vacuum pressure for at least 2 seconds after solder extraction is accomplished.

Items that are essential to effective use of the SODR-X-

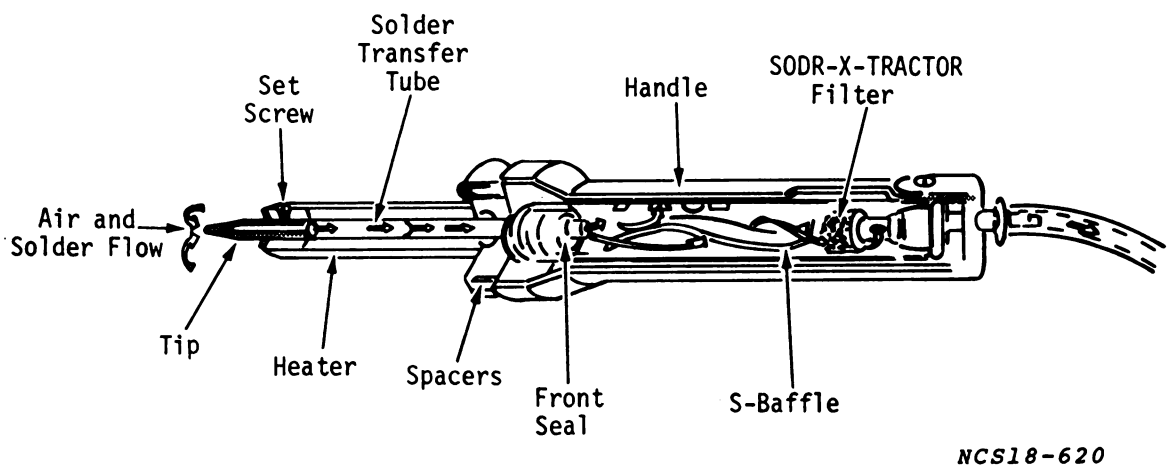

Figure 7-29. SODR-X-TRACTOR.

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TRACTOR are proper tip selection and care and maintenance of the unit. Care and maintenance will be covered later in this section. The key factors in making proper tip selection are: match the tip to the work; insure that the tip fits loosely over the component being desoldered (this provides the necessary clearance for air and molten solder flow); insure that the outer diameter of the tip is always smaller than the width of the pad so that the unit does not come in contact with the substrate of the circuit card; make sure that the selected tip extends approximately 5/8-inch beyond the heater body; and always use the largest tip that can be safely applied to the surface being desoldered.

The setscrew at the end of the heater unit is treated with a special factory-applied lubricant and should not require additional lubrication. However, loosen this setscrew at least once during each 8 hours of operation to prevent possible seizing.

Striptweez, thermal wire stripper. The striptweez unit, shown in figure 7-30, is capable of stripping wire gauges of #12 through#30 AWG; and, with care, can be used on wire gauges to#43. Figure 7-31 illustrates the three-step procedure used to strip a coaxial cable. First, place the wire between the blades at the desired length to be stripped, then clamp the blades to the insulation. While maintaining light pressure on the insulation, depress the foot pedal to heat the blades. The blades should penetrate the insulation in approximately 2 seconds or less. As penetration occurs, slowly rotate either the wire or the stripper in a circiular motion to achieve complete penetration. Do this operation as quickly as possible to prevent possible overheating and damage to the center conductor. Once complete penetration has occurred, release the foot pedal and allow the blades to cool for a moment, then remove the insulation. Now, push back the shield and repeat this procedure on the inner insulation. Finally, trim the shield to the desired length.

Minichine system. The minichine(TM), shown in figure 7-32, provides for a number of different machining operations to aid you in your repair work. Included in its functions are the following: abrasive removal of coatings; slitting inaccessable part leads; slitting parts, bonds, and housings; routing of coatings; removing standoffs or terminals without damaging the circuit card; and, finally, drilling small diameter holes. Please consult your operating manual for specifics on using this accessory.

Resistweez. The resistweez(TM) resistance heating unit, shown in figure 7-33, can be used to accomplish a broad range of heating and soldering work when it is undesirable, or not possible, to use a standard soldering iron. It provides a very localized heating surface that may be used to solder terminals, connector pins, etc. The following guidelines are provided for using this system.

a. Insure both the tweezer tips and the workpiece are clean to provide low-contact-point resistance.

b. Apply power to the unit only after the tweezer tips have been engaged to the workpiece.

c. Insure that power is off prior to disengaging the unit from the workpiece. (These first three steps will reduce the possibility of arcing.)

d. To avoid possible damage, apply power only long enough to reach the solder melting point.

You will find that using the resistweez unit will both simplify and improve many of the soldering tasks you are required to accomplish.

Thermopart unit. The thermopart unit provides an efficient and controllable means for thermoparting and desoldering. Figure 7-34 shows that the unit consists of a pencil-like holder and an interchangeable blade. All PACE systems come with a standard *V-shaped* blade that can be modified

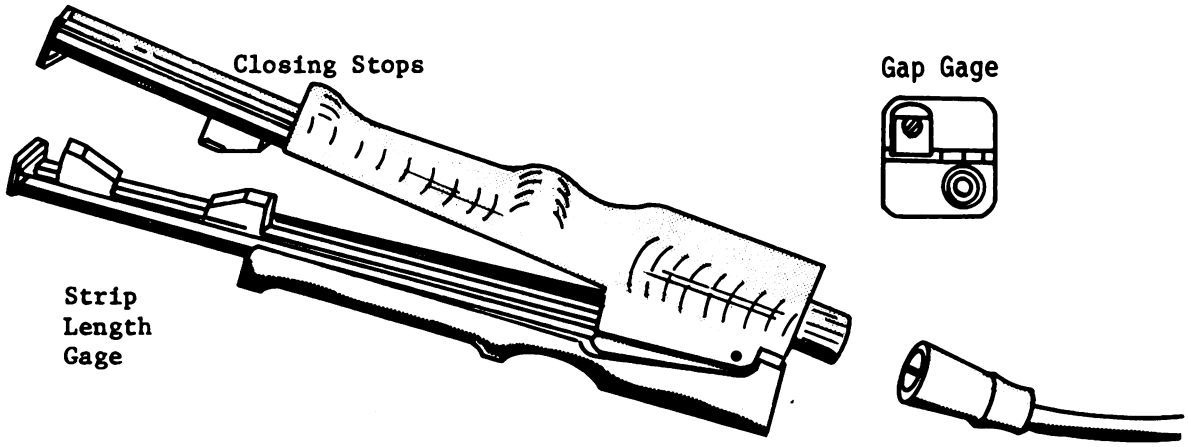

Figure 7-30. Thermal wire strippers. NCS18-619

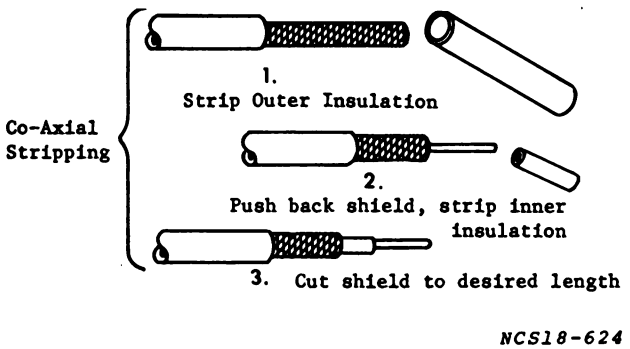

Figure 7-31. Thermal stripping.

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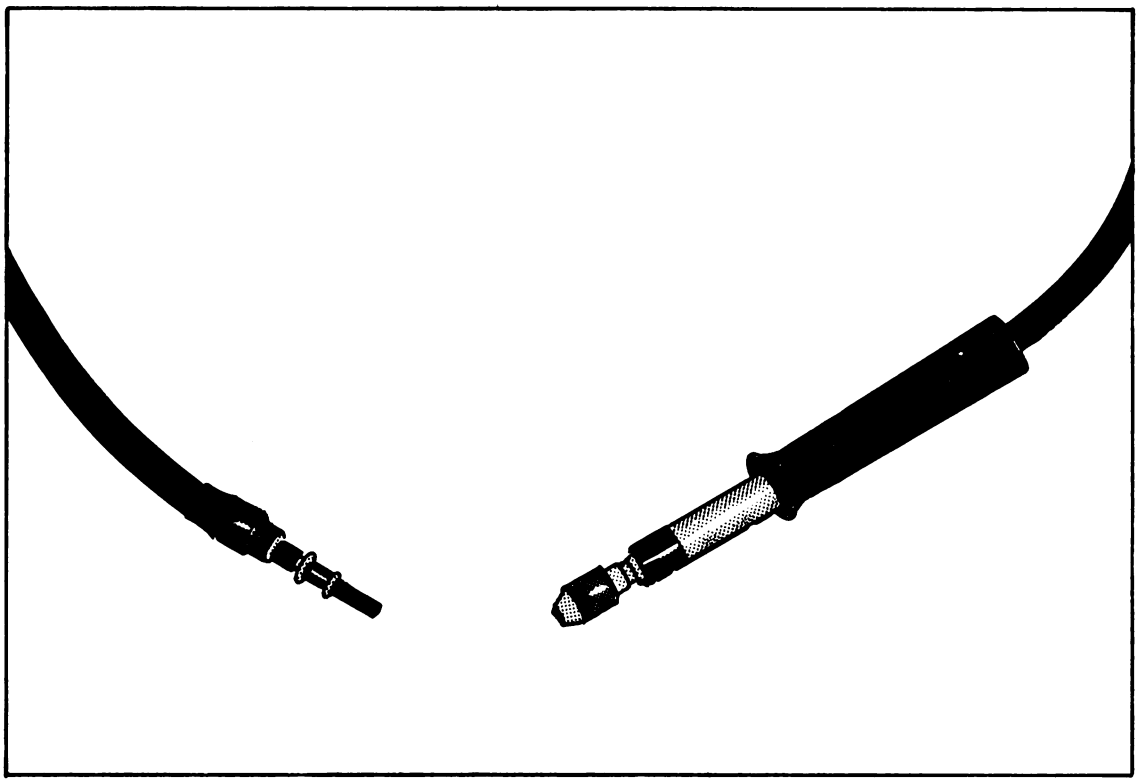

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Figure 7-32. Minichine (TM).

(bent 90°, etc.) when required to accomplish almost any thermoparting or desoldering task.

Many of today's electronic circuit cards are coated with compounds that range from a simple varnish to a two-part epoxy coating of extreme hardness. The thermoparting unit can be used to remove all of these. The primary caution that should be exercised when removing any coating is setting the right temperature. As a general rule, with heat applied, an epoxy surface will granulate and a poly-u surface will soften at the point removal is possible.

The thermopart unit may be used to accomplish a variety of desoldering jobs and should be used whenever you are desoldering clinched leads. To unclinch a lead, heat the solder until it melts and then *lift* the lead from the pad; *do not pry,* as prying may damage the pad.

Lapflo soldering system. A large percentage of round and flat leads terminate in a lapjoint such as the one shown in figure 7-35. Soldering a lapjoint is a two-part operation that has been made much easier with the creation of the lapflo soldering system. This procedure requires that you first tin the pad, then solder the lead to this prepared surface. Below are listed the procedures required to accomplish this task.

a. Using a typing eraser, thoroughly clean each pad so that its surface is shiny and bright.

b. Lay solder the length of the pad; then, using the flat tip of the lapflo element, clamp the solder to the pad.

c. Energize the unit and observe that the solder completely wets the pad surface. This should be done as quickly as possible to prevent overheating.

d. If a pad requires reheating to complete the wetting process, insure you allow the surface to *cool down* before you reapply heat. This will also help prevent damaging the pad.

e. After tinning all pads, form the leads of the component to be soldered so they make uniform contact with each pad. Failure to do this may result in a cold solder connection.

f. Make sure the component is properly *oriented* before soldering i.e., insure that pin N1 is to be attached to pad N1, etc.

Now, using the power level used to tin each pad, apply heat to the lead and observe the formation of a lapjoint. Deenergize the unit and allow the connection to cool for a few seconds prior to removing the lapflo element.

Conductweez soldering unit. The conductweez soldering system provides heating and soldering capabilities that, until now, have been unavailable with resistance-type devices. The resistance-type (resistweez) system transmits heat by means of passing a high level of current through the workpiece. Although this method does provide high-speed localized heating, it can cause arcing due to the difference in contact resistance, or it may damage the workpiece because of its high level of current flow. The conductweez system, shown in figure 7-36 overcomes all of these deficiencies. It utilizes a pair of pulsed electrodes that transmit heat through the workpiece by means of conduction (just as a standard soldering iron does, but from both sides simultaneously). By using a conductive means of heat transfer, the problems of current flow and arcing are eliminated. The

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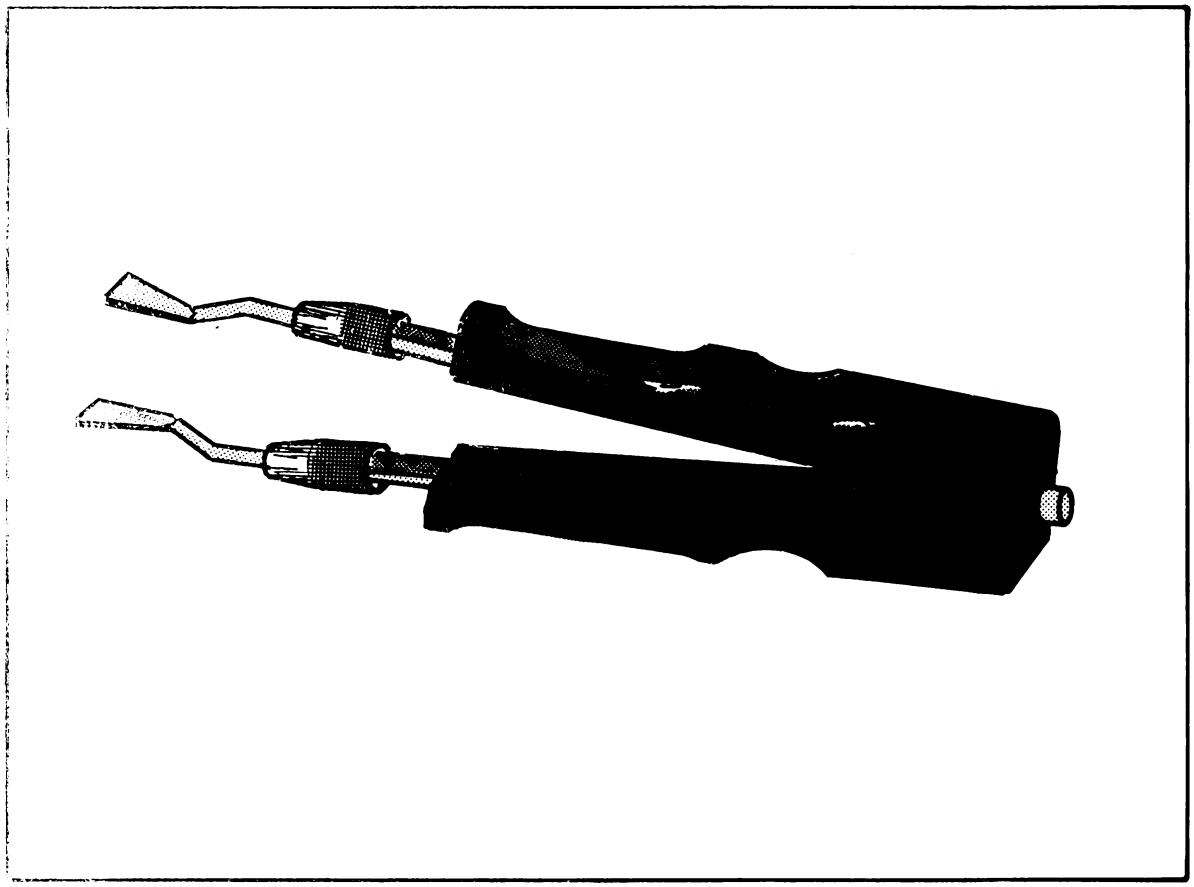

Figure 7-33. Resistweez (TM).

conductweez system should be used in all cases where the current-handling capability of the workpiece is in question. In particular, this system is well suited for cross-wire soldering and for withdrawing soldered-in clipped leads.

Exercises (059):

1. What can be accomplished with the environmental probe?

2. Give at least three requirements for selecting the proper tip to be used with the SODR-X-TRACTOR.

3. When using the resistweez unit, why is it important to clean both the workpiece and the tweezer tip?

4. What is the most important caution that should be taken when using the thermopart unit?

5. What is the purpose and advantage of using the conductweez soldering system?

060. Describe the care and maintenance procedures used with the PACE station.

Care and Maintenance. Routine care and maintenance procedures for the PACE station normally consist of nothing more than placing a few drops of lightweight oil where it is needed and cleaning those elements that require it. Presented here are some of the most common procedures that you should accomplish.

Periodic lubrication. If the setscrew on the SODR-X-TRACTOR is not the original, it should be removed and coated with an antiseizing compound at least once during each 8 hours of operation. If you are in doubt about whether the screw is original, coat it.

CAUTION: When replacing the tip of the SODR-X-TRACTOR, insure the setscrew is tightened no more than one-fourth of a turn beyond the point that it first makes contact with the tip. Any further tightening will cause the tip to collapse and prevent proper operation.

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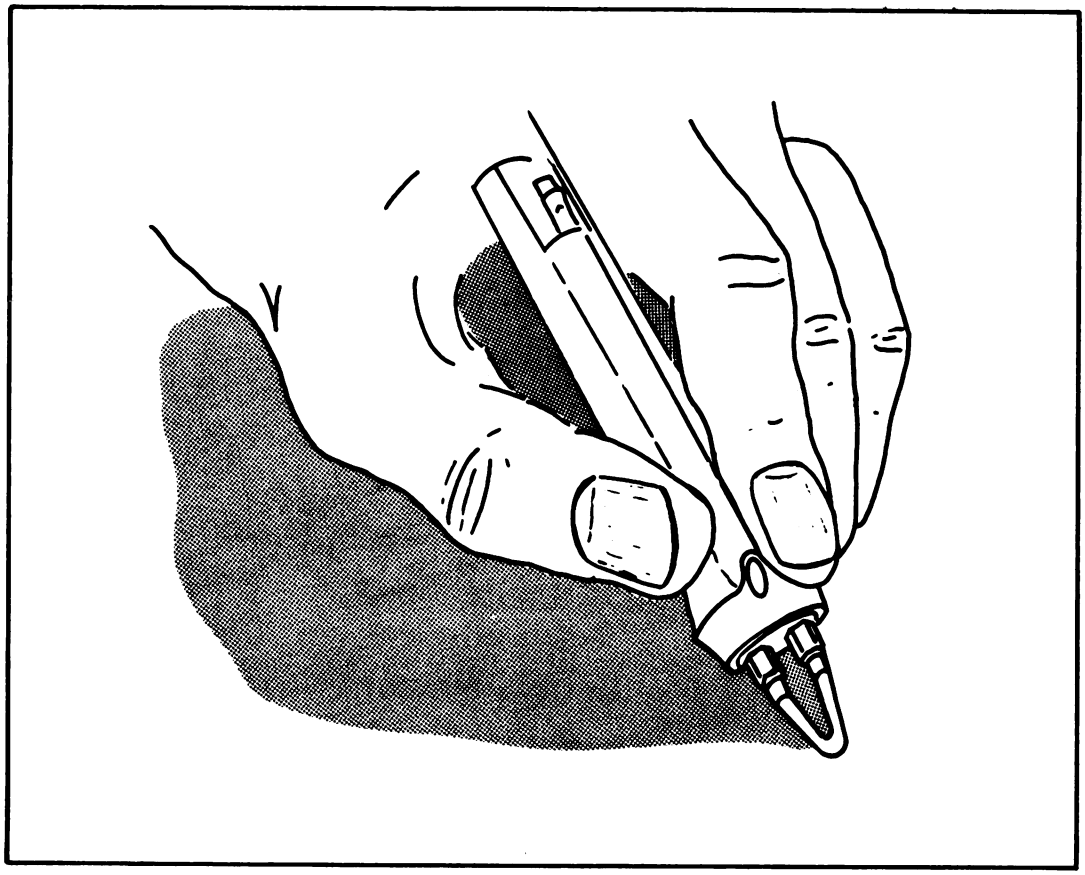

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Figure 7-34. Lapflo soldering unit.

The minichine requires that the spindle assembly be oiled at least once during each 10 hours of operation. To do this, place a few drops of lightweight oil in the hole provided. Should you notice a vibration in the shaft assembly, apply a few drops of oil to the space between the drive-shaft key and the grooved end of the assembly. Then place the unit on end so the oil is allowed to drip down into the sheath.

Cleaning. The SODR-X-TRACTOR should be cleaned as often as necessary to maintain full vacuum flow. The normal cleaning procedure is outlined in figure 7-37. As shown, first remove the tip and clean the heater assembly with a wire brush. Then, clean the glass chamber and the S-baffle with the wire brush; if necessary, coat them with a light coating of mineral oil to aid in the cleaning. The filter at the back of the glass chamber should be replaced as often as necessary to maintain a full vacuum flow. Finally, reassemble the unit as shown. Also, insure that the S-baffle is securely fitted away from the heater; the baffle may be bent, as necessary, to insure a firm fit.

Figure 7-38 shows a heater blockage. This usually happens during solder removal because vacuum flow was not maintained long enough. To clear this blockage, remove the tip and set the heat to maximum. Now, melt approximately 18 inches of solder into the heater tube. Insert a brass or copper rod approximately 3/32 inch in diameter into the heater tube. The solder and rod will transfer the necessary amount of heat to melt and clear the blockage.

Exercises (060):

1. Describe the care and maintenance procedures that should be used with the minichine unit.

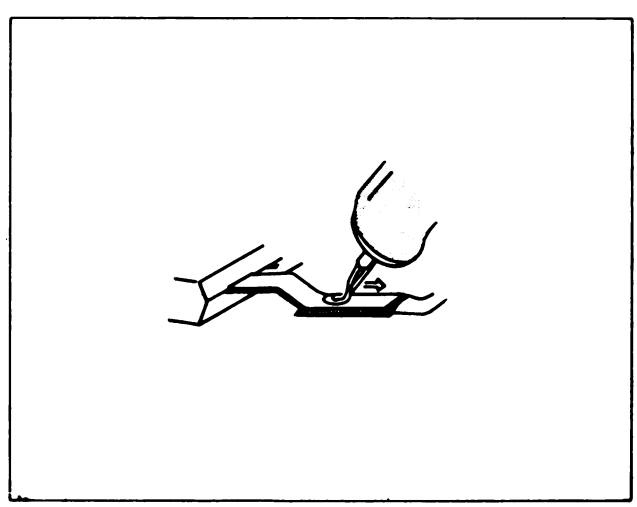

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Figure 7-35. Lapflo soldering.

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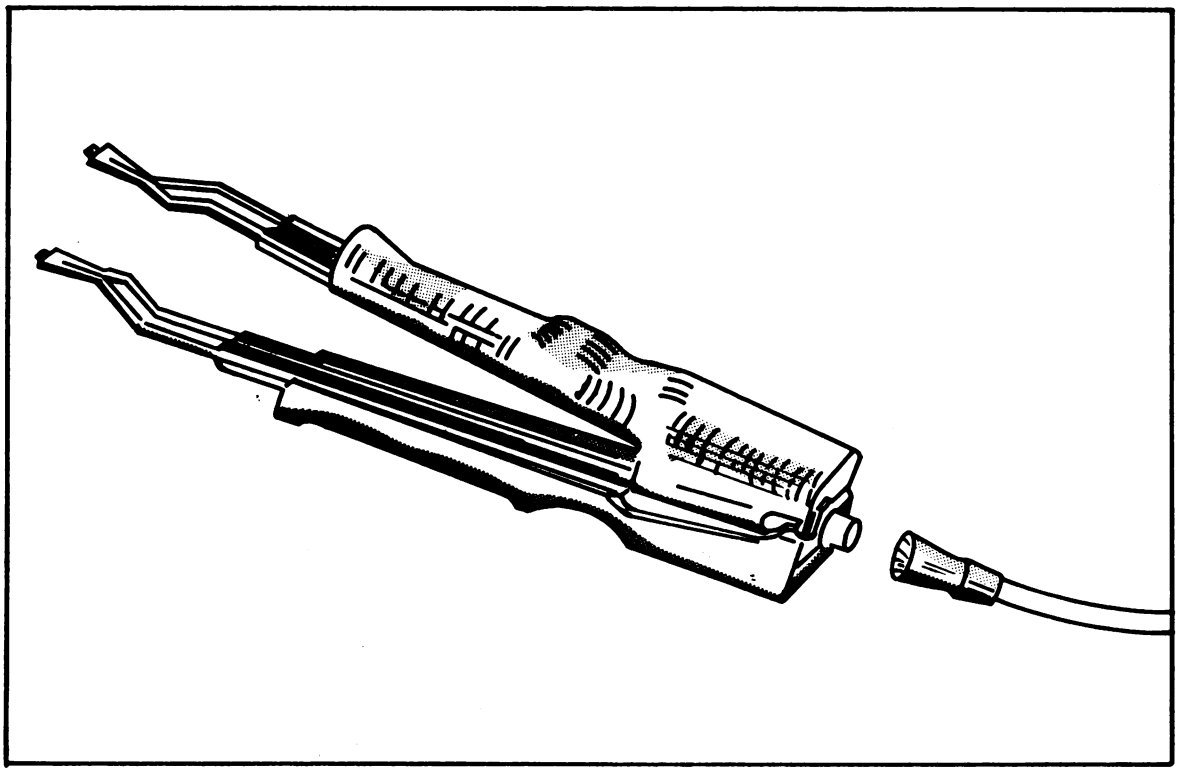

Figure 7-36. Conductweez.

2. What dictates how often the filter in the SODR-X-TRACTOR is replaced?

7-9. Fabricating Cables

As a radar repairman, you are required to fabricate cables for electronic equipment, and it is your responsibility to insure that they are correctly made and checked. An improperly constructed cable can cause electronic failure at a critical time, and it can damage components in the equipment with which it is used. Faulty cables can even cost the lives of operator and maintenance personnel. You can see how important it is for you to know the proper procedures for constructing, inspecting, testing, and repairing cables.

The material used in cable construction must meet all the specifications outlined in the TCTO, the equipment technical manual, or the authorization for the particular installation. You can do good work by closely observing and following the directions given in these references.

061. Cite key points in the procedures for fabricating, binding, and tracing a multiconductor cable.

Multiconductor Cables. Multiconductor cables have from two leads to many leads. In this type of cable, several different wire sizes may be needed, depending on the amount of current each wire must carry. The amount of insulation on any lead is determined by the potential along the lead. In most cases, high-voltage cables are fabricated at the factory. Extremely high voltages use a special high-voltage cable. You can find the exact specifications for all multiconductor cables used with a given item of equipment in the equipment's technical order.

Complete fabrication instructions should be available to you; but reviewing the following steps in constructing multiconductor cables will be useful:

(1) Obtain the cable wire and cable connectors.

(2) Obtain the cable tags, soldering lugs, spaghetti insulation, plastic electrical tape, and lacing cord.

(3) Lay out the proper tools in your work area.

(4) Disassemble the connectors and make sure that they are clean (see fig. 7-39, A.)

(5) Clean and tin the connector pins (wiring cup ends) (see fig 7-40).

(6) Place the connector insert into a vise, the wiring cup side up so that the pins are in horizontal rows. Be careful not to crack the inserts by overtightening the vise.

(7) Cut the wire to the specified length. Strip and tin about ¼ inch of one end of each wire (see fig. 7-39, C.)

(8) If shielded wires are used in the cable, push the shielding back about 1½ inches.

(9) Slide a 5/8-inch length of spaghetti insulation of the appropriate diameter on each wire at the stripped and tinned end (see fig. 7-39, C).

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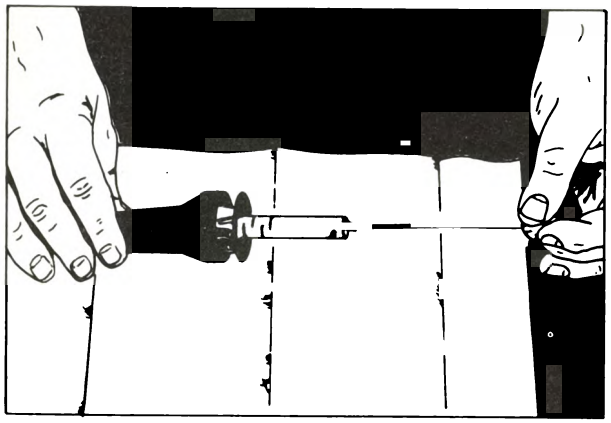

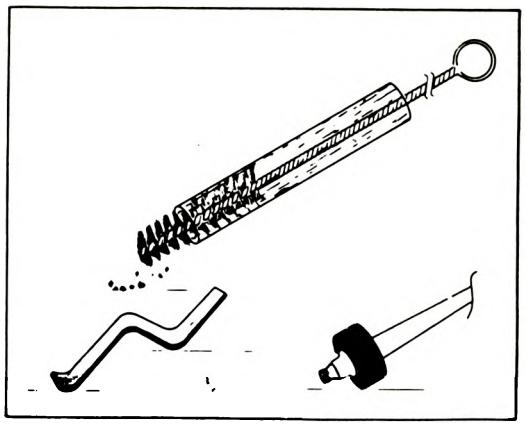

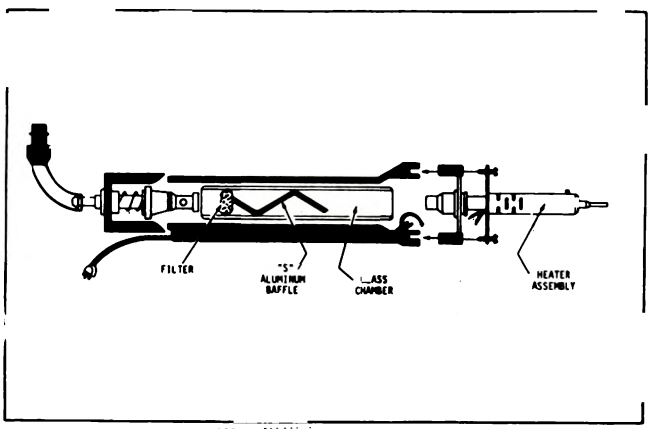

Figure 7-37. SODR-X-TRACTOR care and maintenance.

(10) Solder each wire into its proper pin, beginning with the row of pins at the top and working across and down. Heat the connection pin solder cup sufficiently to melt the solder in the cup. Insert the tinned end of the wire into the cup and remove the soldering iron from the pin (see fig. 7-40). Do not move the wire until the solder has set. After the connection has cooled, slide the spaghetti over the connection. Be very careful not to burn the insulators or to overheat the connector insert. Otherwise, short circuits or leakage can result.

(11) Wrap the cable with five or six turns of plastic electrical tape next to the ends of the spaghetti. Taping holds the spaghetti in place over the connections. If you are using shielded wires, bond the shielding to two or more pieces of scrap shielding, which should extend out of the cable for a few inches. These will be soldered to a grounding lug, which will be attached later to one of the screws on the cable clamp.

(12) In some instances, the shielding is not grounded but is connected to other connector pins. In such a case, prepare and insulate the wire as before; then solder the pigtail lead from the shield to the proper connector pin.

(13) Remove the cable connector insert from the vise.

(14) Reassemble the connector, tightening all of the parts except the cable clamp, which must be left loose to allow the cable covering to be inserted later (see fig. 7-39, A and B).

(15) Arrange the cable wires neatly with no excessive

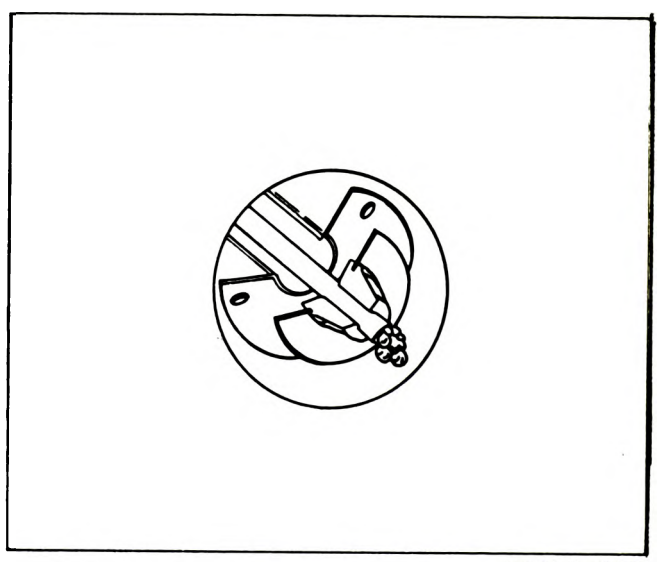

Figure 7-38. [illegible] blockage.

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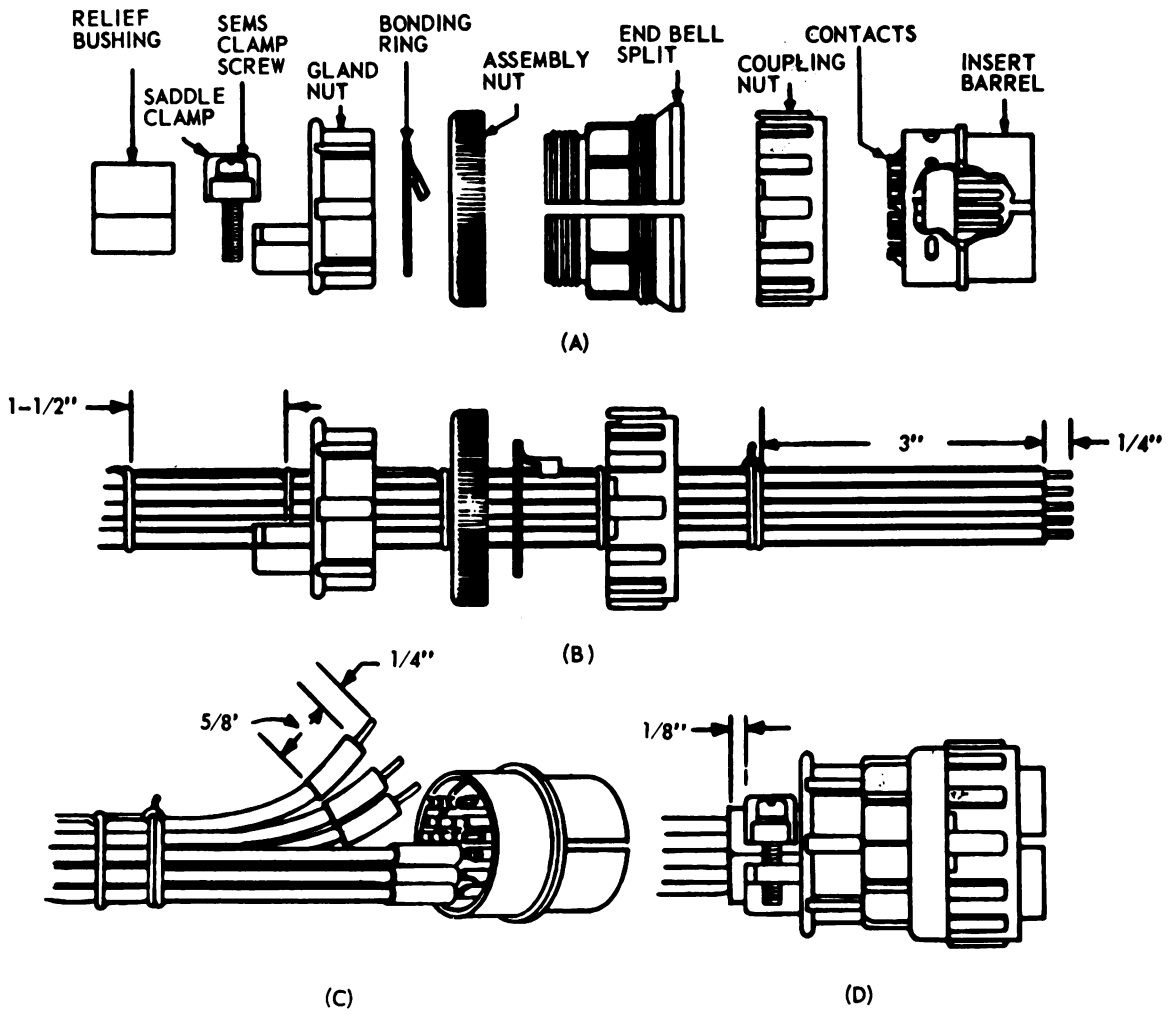

Figure 7-39. Multiconductor cable.

twists or tangles. These can affect the length of the wires.

(16) Lace the cable. Ribbon-type lacing cord is preferred to round cord because it minimizes insulation damage. (Proper lacing techniques are covered later in this chapter.)

(17) Tape the unstripped ends of the wire together for about the first 6 inches with a wide strip of adhesive tape.

(18) When you measure the plastic outer cable housing, allow an additional 2 inches of slack for each 10 feet of cable length.

(19) Use tracing cloth powder to facilitate pulling the cable through the housing. Powder the cable wire—especially the taped end—and the inside of the cable housing.

(20) Tie the taped end of the cable to a metal rod. Push the rod through the plastic sheath and fasten the exposed end of the rod in a vise. Pull the housing over the bundle of wires.

(21) Cut a small hole in the cable housing about 2 inches from the assembled connector end and pull the shielding ground wires through.

(22) Work the housing under the cable clamp on the connector as far as possible. Tighten the cable clamp to hold the plastic housing in place.

(23) Solder the ground shielding wires to the soldering lug and fasten the lug to the connector cable clamp.

(24) Now pull the cable housing far enough onto the cable to allow you to work with the taped end.

(25) Mount another connector in the same way on the other end of the cable, following the above step-by-step instructions.

(26) Use an ohmmeter and check continuity to be sure that you locate the proper wire to solder to each connector pin. In assembling some cables, the wires do not connect letter to letter. For instance, pin A may be connected to pin D. In such cases, refer to the wiring diagram in the technical manual for each wire connection. If the cable is nonreversible, the ends must be labeled at the time of construction, since a reversal of the cable will cause improper operation and can possibly damage the equipment.

(27) After the solder connections cool, slide the spaghetti over each connection to the connector insert, as before.

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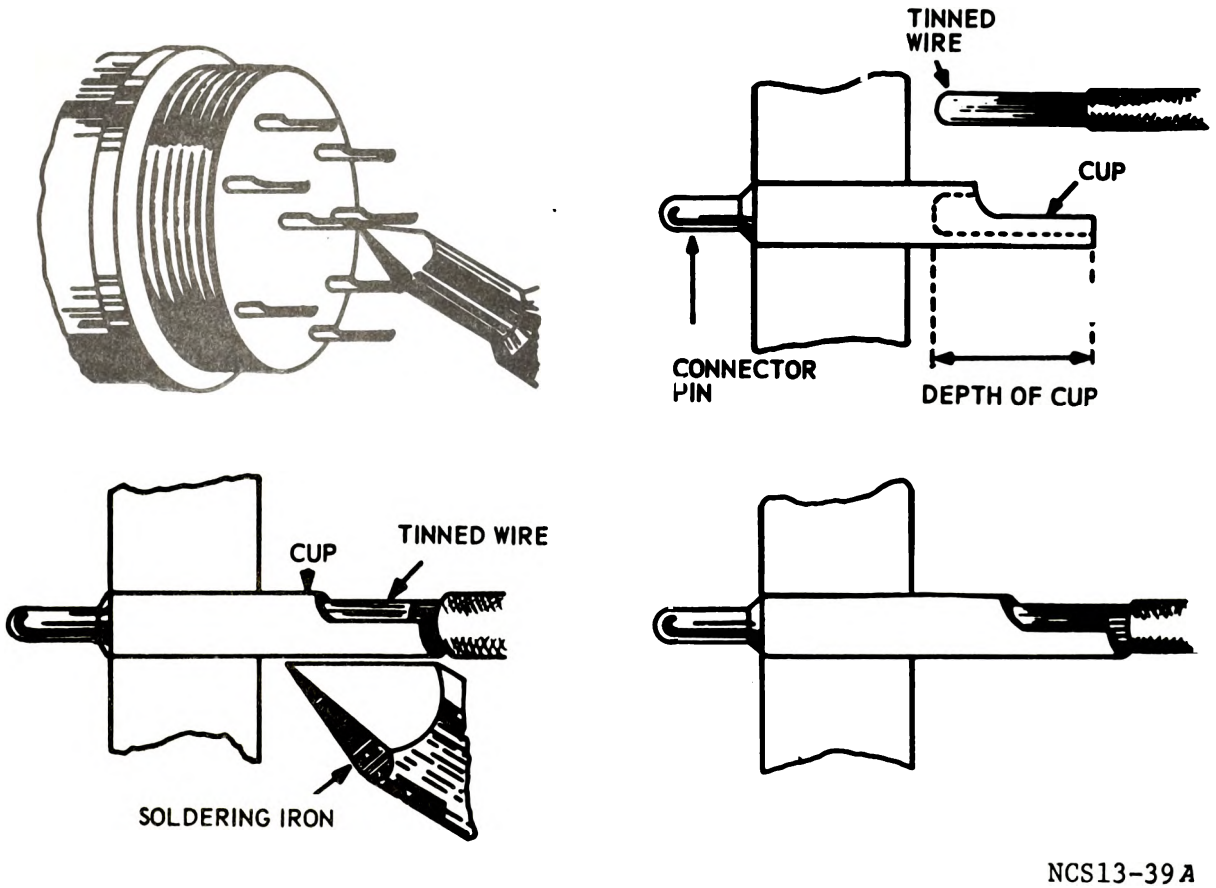

Figure 7-40. Soldering leads to multiconductor.

(28) Remove the cable connector insert from the vise. Reassemble the connector, leaving the cable clamp loose.

(29) Cut a small hole in the plastic cable housing, as before, and pull the shielding ground wires through.

(30) Push the plastic sheath into the cable clamp as far as possible and tighten the clamp to hold the housing in place.

(31) Solder the shielding ground wire to a solder lug and fasten it to the cable clamp.

(32) Attach the cable identification tag, bearing the proper cable number, to each end of the cable near the conductor.

(33) Check the cable thoroughly for shorts, leakage, and continuity. If possible, connect the equipment on the test bench, using the new cable. Operate the equipment to be sure that the cable is serviceable.

Cabling and Harnessing. Proper cabling and harnessing are quite important in electronic equiment. Excessive stress on a cable or harness can break a connection, leading to equipment malfunction and perhaps to a loss of life. To decrease the possibility of undue stress on the cables, they are bound or laced together. The binding or lacing should be sufficiently tight to prevent slippage but should not cut or deform the conductor insulation.

Binding. Binding, or spot tying, is making a series of individually bound wraps at equidistant points along the cable. Cut the cord about 2 inches longer than the length needed to make 12 turns around the harness. Form one end of the cord into a 1-inch loop and place it flat on the harness, parallel to the wiring. Wind 12 turns tightly over this loop and, at the last turn, push the cord end through the loop that extends from under the wrap. Pull the end of the cord that was looped until the loop is under the wrap but only far enough for the two loops to intersect near the center of the wrap (see fig. 7-41). Normally, the loose cord ends will need trimming after the completion of this spot tie.

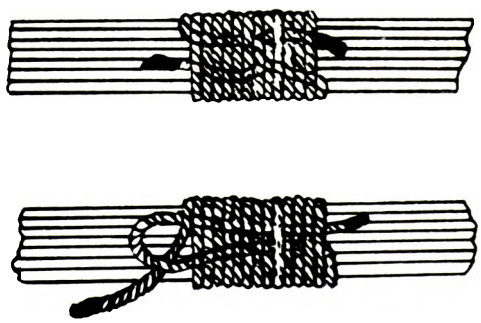

Figure 7-41. Cable lace, spot tie.

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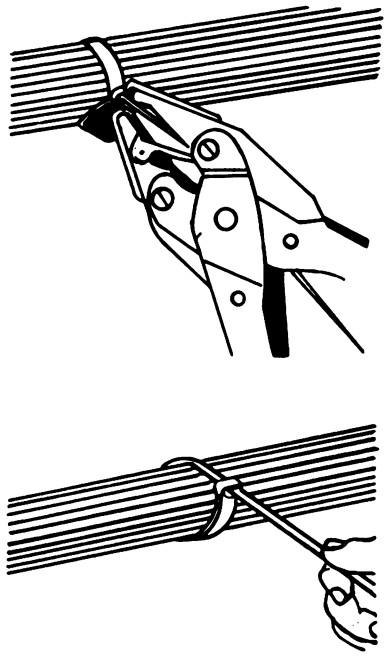

NCS13-47

Figure 7-42. Nylon strapped spot tie.

Another method of spot tying is done with a nylon strap (see fig. 7-42). Slip the nylon tie around the conductors, thread it through the tie eye, and draw it up tight.

Lacing. Cables should be laced with a ribbon-type lacing cord (in preference to round cord) to minimize insulation damage.

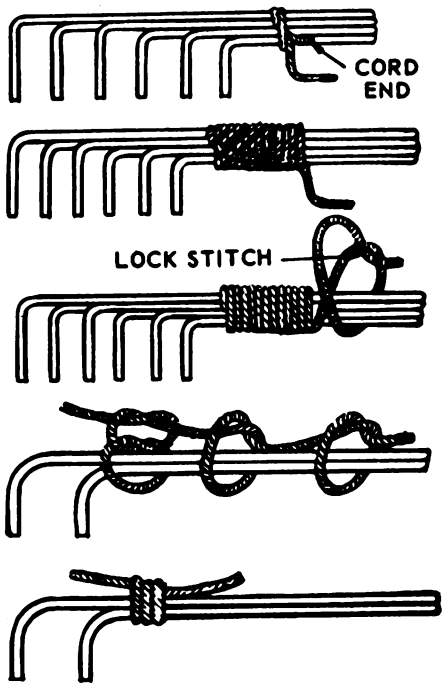

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Figure 7-43. Cable lace start.

To start lacing, lay one end of the lacing cord alongside the principle cable, pointing in the direction of the proposed harness. Secure the end of the cord by winding approximately 4 turns of cord over it, and continue wrapping until you have wound a total of 12 turns around the principal cable (see fig. 7-43). Secure this wrap with a lockstitch made by forming a loop, passing the cord over and then through the loop, and, finally, pulling the cord tight (fig. 7-43). To form secure stitches along the cable assembly, use either single or double lockstitches.

You form the single lockstitch by lacing the cord over the loop (fig. 7-44, A). Never lace the cord under the loop (fig. 7-44, B) because it would loosen. Lacing over the loop locks the cord tight. As the lacing advances, reform the wire to insure a neat and firmly bound cable (fig. 7-44, C).

The double lockstitch is formed in the following way:

(1) Take the lacing cord coming from the starting point and loop it over the harness. Bring it around behind the harness and insert it through the loop, as shown in figure 7-45, A.

(2) Tighten the knot, leaving a loop between the starting point and the knot, as shown in figure 7-45, B.

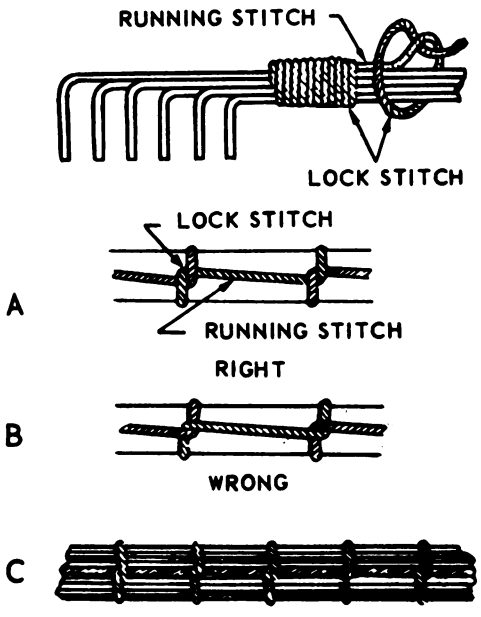
(3) Insert the end of the lacing cord through the loop, leaving a loop through which the end of the cord is again inserted (fig. 7-45, B and C).

(4) Tighten the entire stitch, as shown in figure 7-45, C and D).

(5) Continue lacing, using the same method, until the job is completed.

All lacing should follow the top of the harness, and, when possible, all knots or other irregularities should be hidden from view when the cable is installed.

Figure 7-46 illustrates the procedure for terminating the cable lacing. Wrap 4 turns of cord next to the last lockstitch



NCS13-42

Figure 7-44. Single lockstitch.

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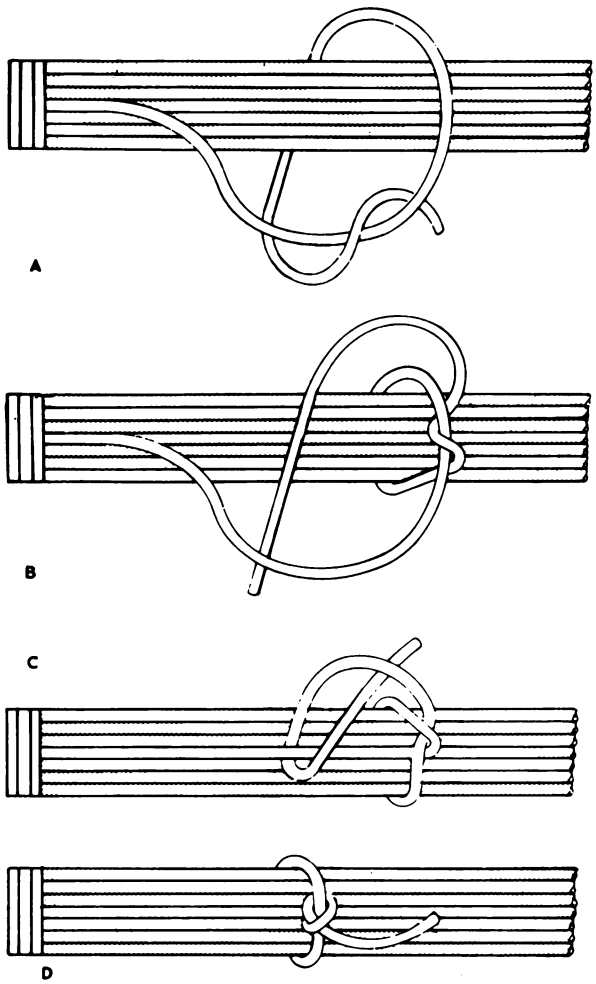

Figure 7-45. Double lockstitch. NCS13-43

and then form a separate piece of cord into a 2-inch loop and lay it alongside the cable. Wrap 8 turns of lacing about the loop and draw the end of the lacing cord through the loop. Pull both ends of the loop carefully to draw the cord end underneath and out of the wrap. Pull the cord end tight, locking the wrap, and then cut the ends to approximately one-fourth inch.

Breakouts. Branches and subbranches, including single leads, are usually referred to as breakouts. A single-lead breakout should be preceded by a lockstitch (fig. 7-47, A) without any variation in the distance between stitches. Any breakout of two or more wires should be laced. When a group of wires is branched from a cable (fig. 7-47, B), wrap a lockstitch and then 6 turns firmly about the main cable; then make another lockstitch adjustment to these turns.

Exercises (061):

1. What determines the size of wire to be used in a cable?

2. Describe the proper procedure for placing a connector insert into a vise.

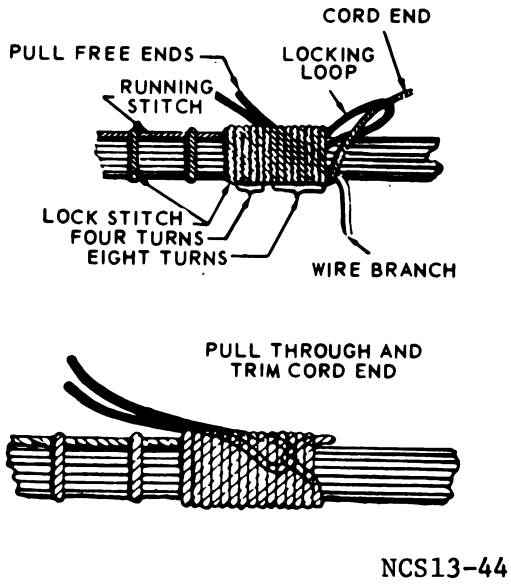

Figure 7-46. Cable lace termination.

3. What length of spaghetti insulation should you use when fabricating cables?

4. What length of outer cable housing should you use for a cable that is 20 feet long?

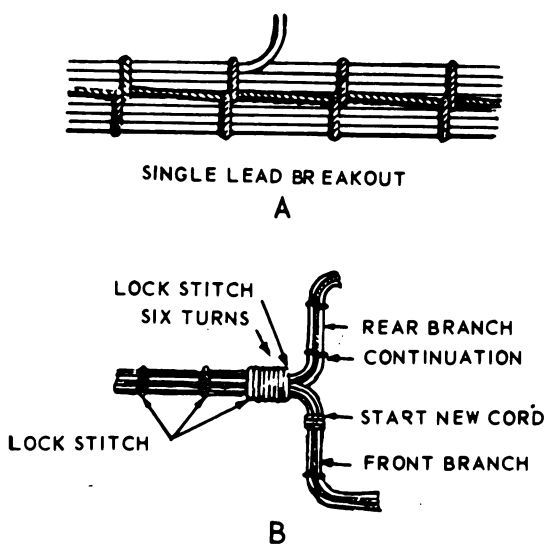

Figure 7-47. Cable branching.

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5. Describe the steps in binding a cable with lacing cord.

6. Why is ribbon-type lacing cord perferred when binding a cable?

7. Why must you lace the cord over the loop in the single-lockstitch method?

8. Describe the proper placement of the lacing, knots, and other irregularities.

9. Describe the procedure used to terminate cable lacing.

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Test Equipment

WHEN TEST EQUIPMENT is in good working order and is used properly, it is the most important maintenance tool you have. However, if your test set is in poor condition or you lack a knowledge of its operation and capabilities, it can be one of your worst enemies for maintenance. For example, if you need to measure a voltage that has a critical tolerance, and you use a multimeter, you will waste a lot of time, since most multimeters "load" a circuit to the point that precise, critical readings cannot be obtained.

Many mechanics and technicians seem to forget that most test equipment is electronic and is susceptible to the same kind of damage as any other piece of electronic equipment. You should treat test equipment with the same care and respect that you would give your stereo and TV.

8-1. Multimeter

You use a multimeter many times on equipment and in the shop to check the output of power supplies, to trace circuits when you are troubleshooting, and to indicate to you when you reach the proper adjustment. The following is a description of circuits in a common multimeter.

062. Determine the correct settings for measuring given DC voltages and the necessary precautions to take.

DC Voltage Measurement. In order to understand the need for selecting the proper meter range and function, start by examining the basic meter movement. This movement consists of a movable coil in a magnetic field, as shown in figure 8-1. When a current flows through the movable coil, it sets up a magnetic field around the coil. If the current is in the direction shown, the upper end of the coil becomes a north pole and is attracted by the south pole of the permanent magnet. This causes the meter pointer to move to the right in direct proportion to the amount of current flowing through the coil. Suppose the current needed to move the pointer to full scale in the meter movement is 50 microamperes, and the resistance of the coil is 1,700 ohms. Using Ohm's law, note it takes only 0.085 volt to produce full-scale deflection: E = I X R = 0.000050 X 1,700 = 0.085 volt.

In order to extend the range of the meter, resistor R1 is inserted in series with the coil. Then most of the voltage is dropped across R1 and the remainder across the coil. In other words, if the value of R1 were such that it dropped 99.915 volts and the coil dropped 0.085 volt, a voltage of 100 volts would produce full-scale deflection.

From this explanation, you can see that changing the value of R1 determines the voltage needed to produce full-scale deflection. This principle is used to change the range of the meter. The preceding discussion has been oversimplified, but we will note the principles involved in our next segment on voltage measurement in which various range positions are selected for different values of voltage to be measured.

If you look through a technical order on any radar, you will find that many of the checks contain steps like the following: "Check for + 150 VDC at TP3003" or "Adjust potentiometer R2 until you obtain 2.6 VDC at TP2." Since you normally use a multimeter to perform such checks, let's review the voltage function of the meter.

The multimeter has a range switch, which allows you to select DC voltages of 0.5, 2.5, 10, 50, 250, 500, and 1,000 volts. Further, on some meters, the DC voltage may be checked at a sensitivity of either 1,000-ohms/volt or 20,000-ohms/volt, selected by a function switch on the panel of the instrument. Figure 8-2 illustrates and identifies the simplified circuits for both sensitivities. Notice that, when you select the 1,000-ohms/volt sensitivity, an additional shunt resistance is inserted in parallel with the meter movement, providing a bypass path for some of the current. This arrangement increases the total input current required for full-scale deflection to 1 mA. Since the instrument's operation is primarily the same regardless of whether the 20,000-ohms/volt or the 1,000-ohms/volt function is selected, we will discuss only the 1,000-ohms/volt operation. If you know the operation of either function, you can easily understand the other.

With the function switch set at the DCV-1KΩ/V position and the range switch at any position, the simplified circuit in

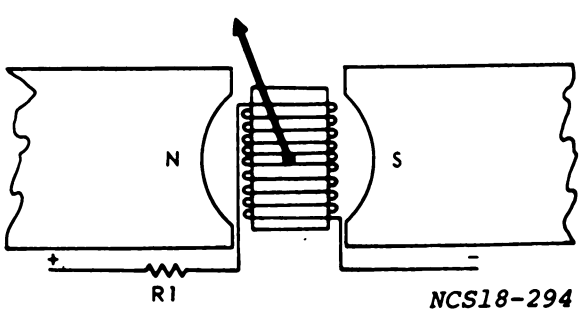

Figure 8-1. Basic meter movement.

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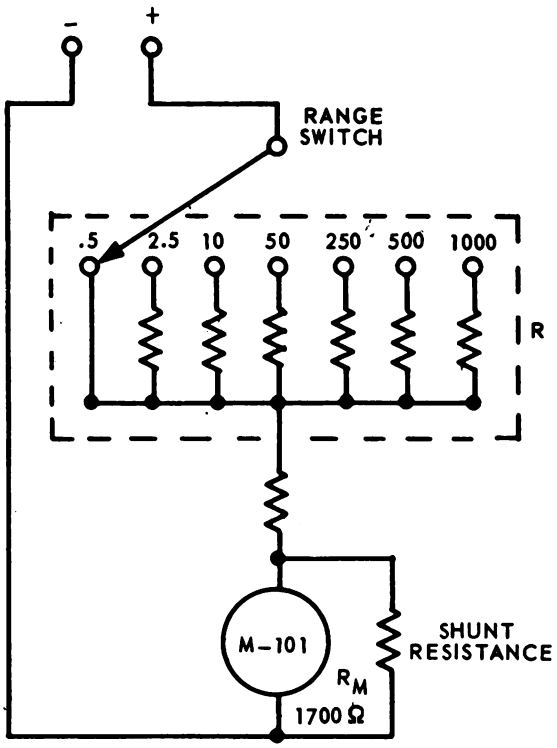
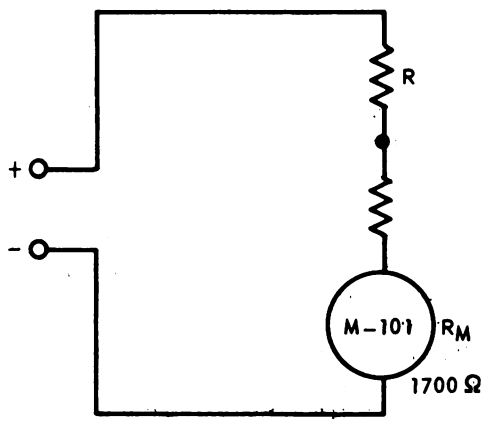


RANGE SETTING	VALUE OF R
.5	0
2.5	2000
10	9500
50	49,500
250	249,500
500	499,000
1000	999,500

1000 OHMS/VOLT

A.



RANGE SETTING	VALUE OF R
.5	0
2.5	40,000
10	190,000
50	990,000
250	4,990,000
500	9,990,000
1000	19,990,000

20,000 OHMS/VOLT

B.

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A. 1,000 ohms/volt.
B. 20,000 ohms/volt.
Figure 8-2. DC voltage measurement circuits.

figure 8-2, A, shows the basic circuit configuration used to check DC voltages. Note in the diagram that the range settings are obtained by the selection of various sized resistors. For example, when the range switch is in range 50, the value of R is such that 50 volts applied across the meter provides full-scale deflection; if the range switch is changed to position 10, then the value of R is such that 10 volts applied across the meter causes full-scale deflection, etc. (The resistance R, illustrated in fig. 8-2, is the same as the resistance identified as R1 in fig. 8-1.)

The circuit illustrated in figure 8-2, B, is, for all practical purposes, identical to that of figure 8-2, A, with the exception of the resistance values used. For instance, if the function switch is set at DCV-20KΩ/V and the range switch is at any position, the circuit reduces to the simplified diagram illustrated in figure 8-2, B. Again, the value of R depends upon the position of the range switch, which is shown in the accompanying table. The total resistance, including the 1,700-ohm meter resistance, provides a 20,000-ohms-per-volt sensitivity for all ranges selected.

While we are talking briefly about DC voltage measurements, let's look at two simple things that can (and too often

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do) cause damage to the meter movement. Refer to figure 8-1 and note what will happen if the meter leads are connected backward in the circuit. The meter needle deflects in the opposite direction and is damaged because it is driven into the stop.

Another feature of DC voltage measurement frequently causes meter damage. If the meter is connected to a source of voltage greater than that which produces full-scale deflection, the current through the movable coil, as shown in figure 8-1, exceeds the 50 microamperes, which the coil is designed for, and the meter needle is forced off the scale. In addition to the precautions just discussed, observe the following precautions when you are measuring DC voltage:

- Keep your hands on the insulated portion of the meter probe.
- Make sure you have the proper conditions to make the desired measurement.

Reread that last statement, "Make sure you have the proper conditions to make the desired measurement."

Refer to figure 8-3. For the purpose of illustration, assume you want to check the voltage at point A to ground. This +28 VDC is needed for energizing relay K1, completing the circuit to the indicator light. The initial conditions for supplying +28 volts at point A are: switch S1 closed and switch S2 pressed. When these conditions are met, there should be +28 VDC from point A to ground. A reading of 28 VDC indicates a normal circuit. A reading of 0 volts on the meter indicates a malfunction in the circuit. However, if one of the switches (S1 or S2) is inadvertently left open, a reading of 0 volts is not an indication of a malfunction but is normal. You can see the importance of being sure that "the proper circuit-under-test conditions have been met" before assuming a malfunction exists.

Before we close our discussion of DC voltage measurements, there is one other precautionary measure you should always observe when using a multimeter. This simple but important precaution relates to measuring high-value DC voltages. When you are measuring high voltages, you should turn off the power in the circuit, set the multimeter to the proper range and function, connect the meter in the circuit, turn the power on, and make the measurement. After you have made the measurement, turn the power off and disconnect the meter. This action prevents any arcing while you are connecting or disconnecting the meter, prevents your being shocked accidentally, and prevents the equipment from being damaged while you are connecting the meter to a "hot" circuit.

Exercises (062):

1. If you were required to measure -30 VDC at TP2, what scale should you select and which lead should you place at TP2?

2. If you were required to measure +250 VDC at TP7, what scale should you select, and which lead should you place at TP7?

3. If you were required to measure 920 VDC, what precautions should you take?

063. Determine the proper settings for selected AC voltage measurements.

AC Voltage Measurement. The procedures for measuring AC voltages are very similar to the DC voltage mea-

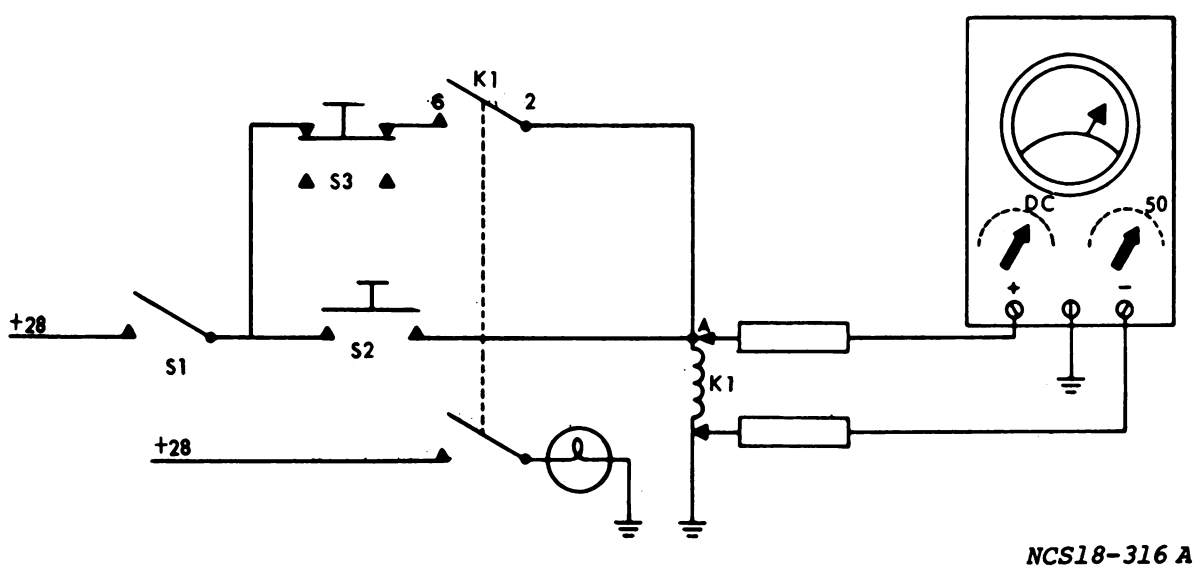

Figure 8-3. DC voltage measurement (proper circuit conditions).

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surement procedures just discussed. Again, the needed controls on the front panel of the multimeter are the function and range switches. With the function switch set at ACV and the range switch at any position, the circuit is reduced to the basic circuit illustrated in figure 8-4 with the values of R as shown in the accompanying table. The ACV ranges are designed for a sensitivity of 1,000-ohms/volts only. The two rectifier sections of CR 101 rectify the alternate half-cycles of the incoming AC voltage, and the resulting pulsating DC is read on the meter. The variable resistor in series with the meter movement is set at the factory and is not an external operator adjustment.

The same basic precautions apply to AC voltage measurement as to DC measurement, except it is not necessary to observe polarities. One additional precaution that should be observed, however, is not related to safety but to the proper use of the meter in AC voltage measurement — the AC voltmeter section of most meters is designed to handle frequencies up to approximately 1,000 Hz. Above this frequency, the voltage readings are subject to inaccuracies due to inductive reactance.

Exercises (063):

1. If you were required to measure 115 VAC at TP4, which function and range should you select, and which lead should you place at TP4?

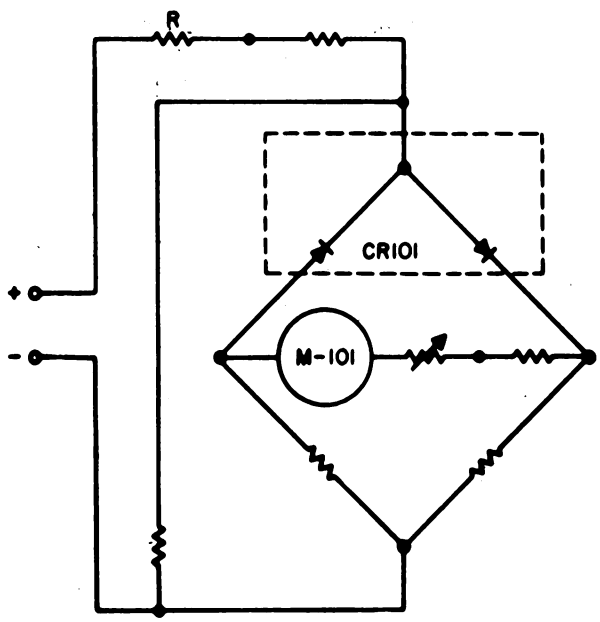
2. If you were required to measure a voltage of 26 volts, 400 Hz, what function and scale should you select?

3. Which of the following readings taken with a multimeter would probably be inaccurate? Why? 56 volts, 2,000 Hz; or 75 volts, 60 Hz.

064. Specify the performance steps in given resistance and measuring procedures.

Resistance Measurement. The multimeter can measure resistance as well as voltage. Although it uses the same basic meter movement shown in figure 8-1, the circuitry is quite different. The circuit contains a battery in series with the meter, as shown in figure 8-5, to provide current for the movable coil. The ohms zero control is a variable resistor that lets you zero the meter for considerable drops in battery voltage. When the meter leads are shorted together, the variable resistor is adjusted to produce a full-scale reading on the meter. The full-scale reading indicates zero as a preliminary step to resistance measurement and perform it thereafter each time you select a different meter range.

If you insert a 50-ohm resistor between the leads, the current in the circuit is reduced and the meter no longer reads full scale. In other words, the size of the resistor inserted between the leads determines the current through the meter and the amount of pointer deflection. The scale is nonlinear and is calibrated to read directly in ohms. With the range switch, you can select ranges of ×1, ×10, ×100, ×1,000, or ×10,000. For example, a direct reading of 67 on the scale with the range switch set at ×100 means that the circuit has a resistance of 67 × 100, or 6,700 ohms.



RANGE SETTING	VALUE OF R
.5	0
2.5	2000
10	9500
50	49,500
250	249,500
500	499,500
1000	999,500

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Figure 8-4. AC voltage measurement circuit.

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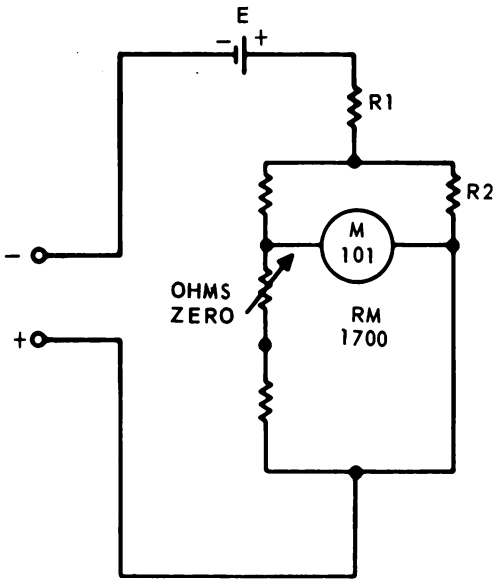

RANGE SETTING	VALUE OF R1 (Ω)	VALUE OF R2 (Ω)	E (VOLTS)
X1	.54	23.75	1.34
X10	17.5	234.8	1.34
X100	175	2583	1.34
X1000	1750	OPEN	1.34
X10,000	226750	OPEN	13.4

Figure 8-5. Resistance measurement circuit.

Look at figure 8-6 and see what else you should remember about the measurement of resistance with a multimeter. This figure shows a portion of the synchronizing circuit located in a typical radar modulator. Notice that the ohmmeter is connected across R630. Should you expect to get a reading of 100 on the meter? No, you should not! If you analyze figure 8-6 more closely, you will see that the current from the meter has two paths to follow. One path is from point A to point B through R630. The other path is from point A to terminal 7 or T603, through the transformer winding to terminal 8, and back to point B. Therefore, the current from the meter is flowing through two parallel paths, and the resistance measured by the meter is the total resistance of the parallel circuit instead of just the resistance of R630. To prevent this situation from occurring, you must disconnect one end of R630 and then measure its resistance. In this way, you can measure its true resistive value. Remember, to get an accurate reading when you measure a specific resistance, you must eliminate any parallel paths.

Another point of procedure to remember when you are measuring resistance with an ohmmeter is illustrated in figure 8-7. This diagram illustrates part of a typical voltage regulator circuit. You want to measure the resistance of

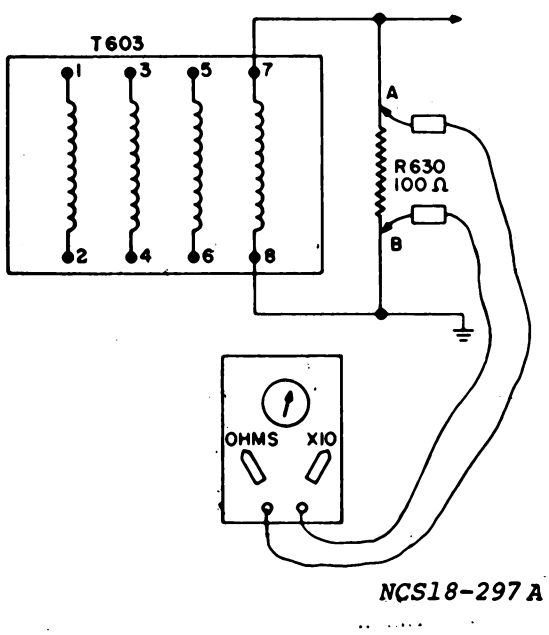

Figure 8-6. Resistance measurement (proper circuit).

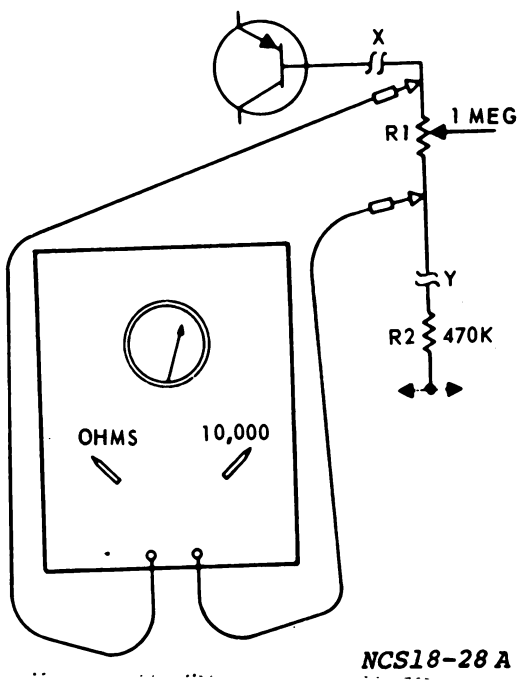

Figure 8-7. Ohmmeter connection.

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potentiometer R1. Of course, you have turned off the power in the circuit and eliminated parallel paths by disconnecting leads X and Y. Now, all you have to do is measure the resistance of R1. But the terminals of R1 are hard to reach, so you place your fingers on the metal tips of the meter leads in order to hold the leads on the potentiometer terminals. Wait a minute though, you have overlooked one little detail—you have placed yourself in parallel with R1. You will probably get a resistance reading of 150,000 to 200,000 ohms, which is the sum of a parallel circuit made up of you and R1. This produces an erroneous meter reading, which could probably lead you down the wrong trail in trouble-shooting a circuit of this type. This, in turn, can waste time and unnecessary replacement of components or parts.

Exercises (064):

1. If you expect to measure 56 ohms from TP3 to ground, what steps should you perform to set up a standard multimeter?

2. If you suspect a bad resistor in a resistive network, what should you do to insure an accurate measurement?

3. Why should you keep your hands off the metal portion of the test leads when you are measuring high resistances?

065. Determine the settings to measure a given DC and state the necessary precautions.

DC Measurement. The remaining major capability of the multimeter is, of course, the DC measurement function. Direct current up to 1 ampere can be measured with most meters. To do this, set the function switch to the DC mA (milliampere) position and set the range switch at one of its positions. Let's review the basic principles and procedures involved in DC measurement.

Refer to figure 8-1, the basic meter movement, again. As we said earlier, the amount of current through the movable coil determines the amount of meter deflection. In the case we are using, the current through the coil needed to produce full-scale deflection is 50 microamperes. What would happen if you put 100 microamperes through the coil? You would damage or burn out the coil. This situation is prevented by placing a resistance in parallel with the coil. The value of the resistance is such that it allows only 50 microamperes thorugh the coil, provided that the range switch is set so that the total current in the circuit is the same as or is less than the range at which the meter is set. For example, when the range switch is set at 50 and a current of 50 mA is measured, 49.95 mA flows through the resistor and 50 microamperes flows through the coil. This produces a full-scale deflection for that range switch setting and reads 50 mA on the scale. In the actual circuit, different values of shunt resistors are used for each setting of the range switch.

Here, as with voltage measurement, be extremely careful to make sure that a range setting of sufficient amplitude is obtained so that the meter needle will not be "pegged" when you are measuring DC. Remember, if the needle does not deflect far enough to get an accurate reading, the range setting can always be decreased to a point where adequate deflection of the meter needle provides a fairly accurate reading.

One other precaution that you must take when measuring DC is to make sure that the meter is properly connected into the circuit. For example, what would happen if you tried to measure the current with the meter connected as shown in figure 8-3? You would burn out the meter because the current would be extremely high. When you measure direct current, you must break the circuit and place the meter in series. In figure 8-3, you could leave switch S2 open and connect the meter across the terminals of S2. With switch S1 closed, you would read the current through K1. Remember, when you are measuring current, the meter must be connected in series.

Exercises (065):

1. If you want to measure the current of 120 mA in a DC circuit, what settings of the range and function switch should you use?

2. What precaution that does not apply to other measurements should you take when measuring direct current?

8-2. Digital AC-DC Voltmeter (LX-2)

The need to measure precise voltages and resistance has led to the development of the digital voltmeter. There are many models available today. The digital voltmeter used in some GCA maintenance activities is the LX-2 (see FO4 located in back of this volume). The instruction manual for the LX-2 is the authority for much of the information in the following segment.

066. Describe the operating characteristics and procedures necessary for making voltage and resistance measurements with the LX-2.

Operating Characteristics of the LX-2. The LX-2 is a compact, highly accurate, portable instrument capable of providing precise AC and DC voltage measurements. It is also capable of measuring resistance accurately. Primarily, this multimeter is used for measurements of AC and DC voltages from 0 to 1,000 volts. You can measure very high DC voltages, from 1,000 to 30,000 volts, with this instrument by using an attenuation probe, which provides an attenuation of 1000:1.

Resistance measurements can be made from 0.1 ohm to 125 megohm. The input impedance of this meter is 10

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megohms on all DC voltage scales and 1 megohm on all AC voltage scales. You can see that the loading effect of this instrument is very small, and it can measure most circuits accurately without affecting the operation of the circuit.

DC voltage measurements. We should go over some of the steps in measuring DC voltage since this is done so frequently.

When you use the LX-2 to perform voltage checks and alignments, you must first perform certain preliminary procedures before measuring the DC voltage. The key preliminary steps are to: (1) connect the guard terminal with the LO terminal using the shorting strap provided, (2) connect the input leads to signal HI and signal LO terminals, and (3) switch the LX-2 on by depressing the POWER pushbutton. You are now ready to place the LX-2 in the proper mode for measuring DC voltage.

Switch into the DC volts mode by depressing the VDC button. Make sure that the EXT REF button is in the OUT position. Next, short circuit the input leads and read the display. It should register 0.0000. If it does not, you can adjust the readout by varying the zero adjust control with a small screwdriver inserted in the hole directly under the VDC button. With the register zeroed, you measure the DC volts by connecting the input leads to the voltage source to be checked. The LX-2 will automatically select the proper range and display the voltage with the decimal point in the proper position to enable you to read the voltage directly. The instrument also displays the polarity of the voltage. The polarity is always displayed as the input HI terminal with respect to the input LO terminal (see FO4). If you exceed the capacity of the LX-2, the indicator directly to the right of the polarity indicator will display the digit "1" to indicate an overrange condition. When this condition exists, you have to use an attenuation probe to read the voltage. The probe provided with the LX-2 permits measuring voltages from 1 kV to 30 kV.

Measuring AC volts. AC voltage measurements require the same preliminary procedures as DC voltage measurements. To select the AC mode of operation, you depress the VAC button. Next, short circuit the input leads and insure that the readout displays 0.000. If necessary, you can zero the readout by varying the AC zero adjust control with a small screwdriver inserted in the hole directly beneath the VAC button. After the zero has been checked, you can measure AC volts by connecting the input leads to the AC voltage of interest. The instrument will select the proper range automatically, displaying the AC voltage and decimal point.

Measuring resistance. The preliminary procedures are the same for measuring resistance as for measuring DC or AC voltages. You switch to the resistance mode by depressing either the KΩ or the 10s KΩ (10MΩ) button. The amount of resistance to be checked determines the range you should use. Next, short circuit the input leads and the register should display 0.000. If it does not, check the DC volts zero. If the DC volts zero is correct, the register is displaying the resistance of the test leads. The LX-2 is now properly adjusted to measure resistance. Connect the input leads to the unknown resistance. The instrument automatically selects the proper range and displays the resistance. In the KΩ mode, the resistance is displayed in KΩ with the decimal point in the proper position. In the 10s KΩ mode, the instrument displays the resistance in KΩ with the decimal point understood to be to the right of the least significant digit, e.g., 12500KΩ.

Exercises (066):

1. What characteristic of the LX-2 insures the minimum loading of an operational circuit under test?

2. Describe the procedures involved in zeroing the LX-2 before making a DC voltage measurement.

3. Describe the decimal placement in the KΩ and 10^4 KΩ modes of operation.

8-3. Radar Test Set AN/UPM-145

The AN/UPM-145 radar test set is a portable, X-band transponder/analyzer. It is used to test and adjust pulse radar, CW radar, and beacon radar systems. The test set replaces the much maligned UPM-10B. Since tests are initiated and controlled by controls provided on the test set front panel, this section is designed to provide you with a working knowledge of these controls.

067. With regard to pulsed radar, state the function of the AN/UPM-145, the purpose of selected controls, and how to convert its peak-power readings.

Function. The planned purpose of the AN/UPM-145 is to test X-band radar power, frequency, pulse repetition frequency (PRF), radar-tracking capabilities, and receiver bandwidth and minimum discernable signal. The set can also be used as a signal generator with continuous wave (CW), pulse modulated (PULSE), square wave (SQW), or frequency modulated (FM) outputs. These generated signals are controllable in frequency, power, PRF, pulse width, range, and range rate.

Controls. In the course of making two tests (transmitter power and receiver sensitivity—perhaps the only routines you will be required to use) certain features will be used, to the exclusion of others. The following narrative will cover only those features you are most likely to use, excluding the more obvious, such as power ON/OFF. The front panel features can be seen in figure 8-8.

RF IN/OUT. RF IN/OUT connector J2 is one of those more obvious items that was to be excluded from this objective. But, there is something you should know about J2. *Damage to the test set may result if maximum input power levels are exceeded.* The maximum peak power that can be applied to the connector is +50 dBm for pulsed radar

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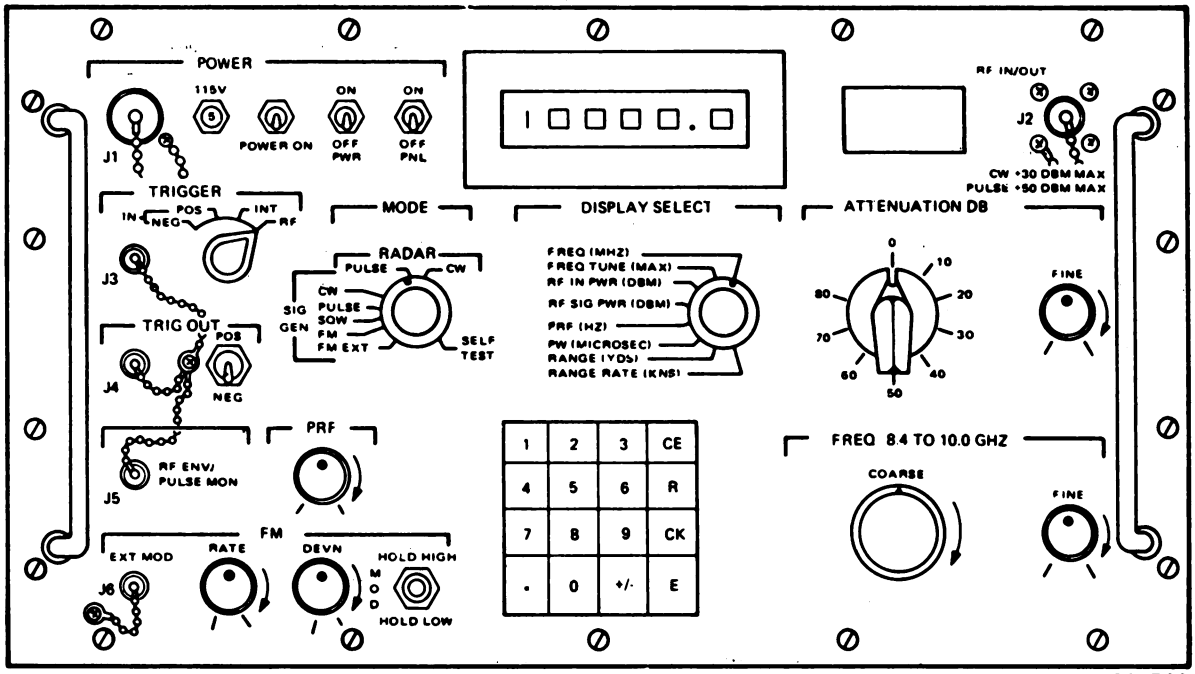

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Figure 8-8. Front panel controls, radar test set AN/UPM-145.

systems. Minimum peak power for the AN/FPM-62 is 65 kW, or about 78 dBm. The AN/GPN-22 has two power levels, 15 kW (71.7 dBm) and 250 kW (84 dBm). Insure that attenuation from couplers and cables is enough to reduce these power levels below 50 dBm prior to the test set connection.

Trigger. When performing MDS checks, the four-position trigger select switch providing for selection of test set triggering, will be set to the RF position. Unless you use the signal generating mode, you should be able to leave the switch in RF, allowing synchronization of the test set by the leading edge of the pulsed RF input. The other positions allow selection of test set triggering, by either the positive or negative edge of input triggers, or internal triggering by the PRF generator.

Mode. Providing for selection of the UPM-145 mode of operation (radar, signal generation, or self-test), the eight-position rotary MODE switch will normally be in the RADAR-PULSE position.

Display select. The display select switch performs two functions. The more obvious use is to select the parameter to be shown on the six-digit numeric display above the switch. The selectable positions and the parameters displayed are described in the following list:

1. FREQ (MHz)—selects direct display of test set oscillator frequency.
2. FREQ TUNE (MAX)—selects direct display of test set oscillator frequency to radar input frequency.
3. RF IN PWR (dBm)—selects direct display of input peak-power level at connector J2. This position used when measuring transmitter power.
4. RF SIG PWR (dBm)—selects direct display of test set output peak power at connector J2. This position used for measuring MDS.
5. PRF (Hz)—selects direct display of radar PRF (TRIGGER switch set to RF), test set internal PRF (TRIGGER switch set to INT), or external trigger PRF (TRIGGER switch set to IN POS or IN NEG).
6. PW (MICROSEC)—selects direct display of generated target pulse width. Also enables keyboard entry of new pulse width (MODE switch set to RADAR PULSE or SIG GEN PULSE).
7. RANGE (YDS)—selects direct display of test set generated target range. Also enables keyboard entry of new range (MODE switch set to RADAR PULSE or SIG GEN PULSE).
8. RANGE RATE (KNS)—selects direct display of test set generated target range rate. Also enables keyboard entry of new range rate (MODE switch set to RADAR PULSE or SIG GEN PULSE). KNS signifies "knots."

The less obvious purpose of the display select switch is to select the keyboard (below the switch) entry mode.

Keyboard. The 16-key keyboard allows you to enter the following parameters, when the MODE switch is set to RADAR PULSE or SIG GEN PULSE modes and the DISPLAY SELECT is in the appropriate position:

1. Pulse width—0.12 to 5.00 microseconds in 0.01-microsecond steps.
2. Range—250 to 40,000 yards in 10-yard steps.
3. Range rate—+2,000 to -2,000 knots in 1-knot steps.

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ATTENUATION dB. A functional group is identified by the ATTENUATION dB heading. Included in the attenuation group are a nine-position rotary switch (attenuation of RF IN/OUT signal from 0 to 80 dB in 10-dB steps) and a potentiometer (FINE, proving continuous attenuation adjustment of test set RF output signal level from +7 to -15 dB).

FREQ 8.4 TO 10.0 GHz. Another functional group, the FREQ 8.4 TO 10.0 GHz controls (COARSE rotary control, and FINE control potentiometer) provide continuous frequency adjustment of the test set oscillator. The COARSE control requires 8 turns (CW) to change frequency from 8.4 to 10.0 GHz, returning to 8.4 GHz when tuned past 10.0 GHz. The FINE control has a 10-MHz range within the COARSE frequency setting.

Transmitter Power. When measuring pulsed transmitter power, the test set provides peak-power readings, whereas the transmitter power parameter is usually listed as average power. The peak-power reading can be converted to average power by the following equations:

AVG = PEAK + 10log (PW/PRI)
AVG = PEAK + 10log (PW x PRF)

where:

AVG	=	average power in dBm
Peak	=	peak power in dBm
log	=	base 10 (common) logarithm
PW	=	pulse width in seconds
PRI	=	pulse repetition interval in seconds
PRF	=	pulse repetition frequency in Hertz

What good do these formulas do you without a log table or a scientific calculator? Not much, so here are some basic figures that should make things easier. At an average PRF of 3,300 and a PW of .18 μsecs, the 10log(PW × PRF) equation equals -33.26. Add that to the peak reading of the test set and you have average power in dBm (not forgetting to add cable and coupler attenuation). The -33.26 is a standard figure that can be used for the AN/FPN-62, if the system matches the figures used. The factors for the AN/GPN-22, at each of two average PRFs, are -25 (3160 PPS) and -24.27 (3740 PPS). PW is 1 μsec.

As an example, if the displayed power for an FPN-62 is +49.0 dBm, cable attenuation is +15.0 dBm, and coupler attenuation equals +24 dBm, peak power equals (44 + 15 + 24) 83 dBm and average power equals (44 + 15 + 24 ffi 32.26) 50.74 dBm. Chapter 2 of Volume 2 shows another method of converting peak to average power.

Exercises (067):

1. What frequency range is the UPM-145 designed to test?

2. What is the maximum peak-power level that can be applied to the input of the radar test set?

3. When wouldn't the TRIGGER switch be in the RF position?

4. How is the DISPLAY SELECT switch used when measuring power?

8-4. Oscilloscope (Type 453)

Each piece of electronic test equipment is designed to serve a purpose. Some have limited usage, others are more versatile. Among the latter is the workhorse of an electronics shop, the oscilloscope. Several oscilloscopes are authorized for use in the Air Force. For our discussion we have selected the Tektronix Type 453, and the following information was obtained from its instruction manual.

This piece of equipment is transistorized, portable, and designed to operate in a wide range of environmental conditions. Because of these factors, the 453 oscilloscope is perhaps one of the more enjoyable oscilloscopes to use.

068. State the characteristics of selected controls and settings on the Type 453 oscilloscope.

Operating Principles and Procedures. Figure 8-9 is an illustration of the control position layout of this oscilloscope. Note that we have divided the panel using hash marks so you can more readily see how certain clusters of controls are physically related.

Oscilloscope inputs. The machine accepts inputs ranging from a DC level up to 50 MHz. Input coupling switches (AC-GND-DC) shown in sections "channel 1" and "channel 2" allow a choice of coupling. For DC levels, the DC position is naturally selected but is also selected for AC signals below 16 Hz, as these would be attenuated too much in the AC position. In the AC position, the DC component of the input signal is blocked by a capacitor in the input circuit. The low-frequency response in the AC position is about 1.6 Hz. Therefore, you can expect some low-frequency distortion. The GND position provides a ground reference at the input of the oscilloscope. The GND position can also precharge the coupling capacitor to the average voltage level of the signal applied to the input connector. This allows you to measure the AC component of signals having both AC and DC components.

Sweep-triggering selection. An input signal is not all that is required; you must also trigger the sweep. The 453 oscilloscope has four means of triggering the sweep. The INT position uses a triggering signal from the vertical deflection system. The source of the internal trigger signal is selected by the TRIGGER MODE switch. When LINE position is chosen, a sample of the powerline frequency is used to trigger the sweep. This is useful in displaying a line frequency component in a complex waveform. The EXT position is used for triggering the sweep by an external signal. The external trigger must be time related to the displayed signal for a stable display. External triggering can be very useful when you are signal tracing in amplifiers, phase-

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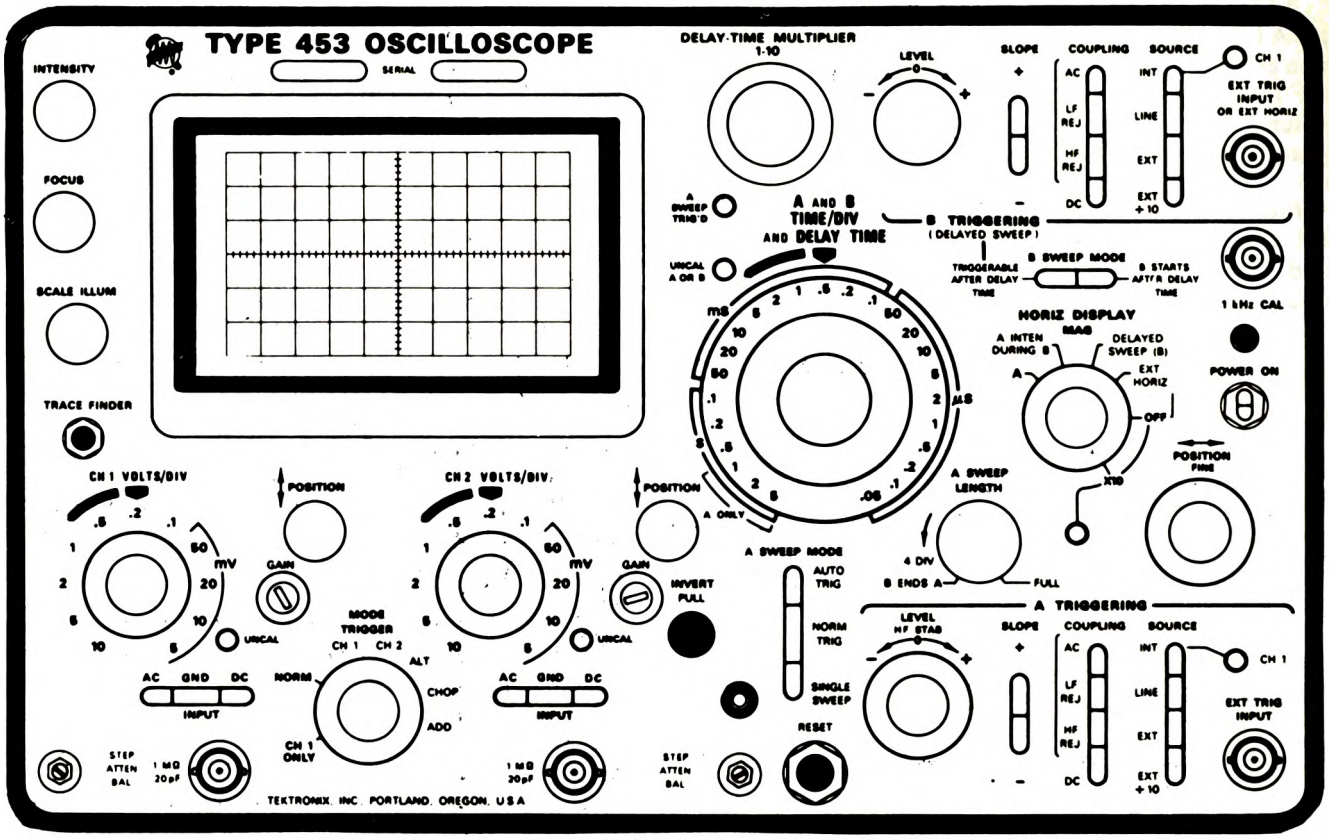
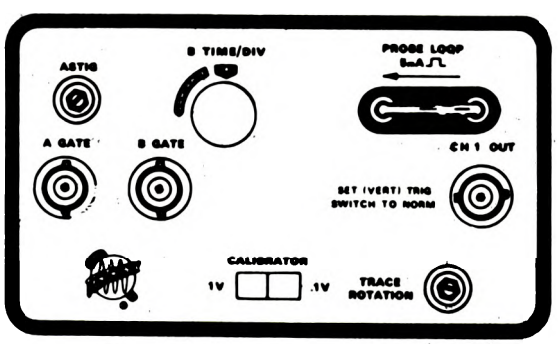
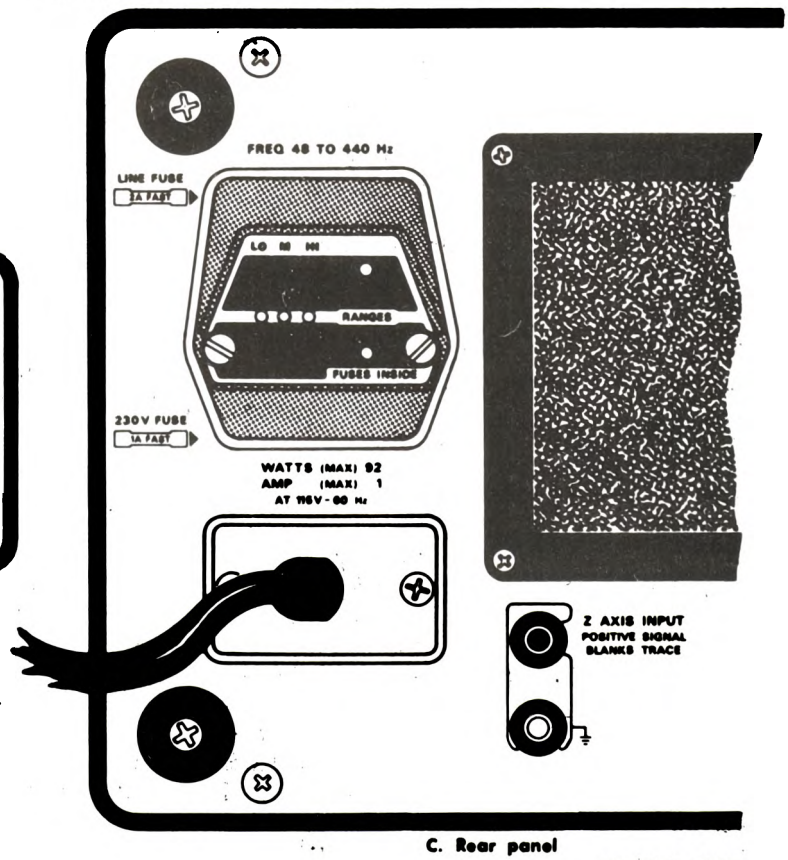


A. Front panel



B. Side panel



C. Rear panel

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Figure 8-9. Control layout chart for Type 453 oscilloscope.

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shifting networks, and waveshaping circuits. Occasionally, it is desirable to broaden the range of the triggering LEVEL control. The EXT ÷ 10 position attenuates high-amplitude external signals 10 times. The LEVEL and SLOPE controls determine what portion of the trigger starts the sweep circuits. Coupling the trigger signal to the trigger circuit is the function of the 4-position COUPLING switch.

Single-sweep operation. This mode of operation is used when the signal to be displayed is not repetitive or variable in amplitude, shape, or time. The single-sweep mode can be used to set up a nonrepetitive signal for photographing.

Single-trace and dual-trace operation. The 453 oscilloscope can display a single trace in the channel 1 (CH 1) or channel 2 (CH 2) mode. However, when two input signals are to be compared, the MODE TRIGGER selector may be placed to the ALTERNATE (ALT) or CHOPPED (CHOP) position. Both modes produce two traces which alternate between CH 1 and CH 2 with each sweep across the CRT. The ALT mode can be used at all sweep rates, but the CHOP mode provides a more satisfactory display at sweep rates below a 50-microsecond/division.

Horizontal sweep controls. The use of the A and B TIME DIV and DELAY-TIME controls will be described in more detail in a later objective. The A and B TIME/DIV switches select calibrated sweep rates for the sweep generators. The A and B VARIABLE controls provide continuously variable sweep rates between the settings of the TIME/DIV switches.

The X10 position of the magnifier (MAG) switch expands the sweep 10 times. The center division of the unmagnified display is the portion visible on the screen in the magnified form. (See fig. 8-10). When the MAG switch is set DIV switch setting by 10. For example, if the TIME/DIV switch is set to .5 microsecond, the magnified sweep rate is 0.05 microsecond/division.

The delayed sweep (B sweep) is operable in the A INTEN DURING B and DELAYED SWEEP (B) positions of the HORIZ DISPLAY switch. The A sweep rate along with the DELAY TIME MULTIPLIER dial setting determines the time that the B sweep is delayed. The sweep rate of the delayed portion is determined by the B TIME/DIV (DELAYED SWEEP) switch setting on the side panel (fig. 8-9, B).

In the A INTEN DURING B position, the display is similar to figure 8-11, A. The amount of delay time between the start of A sweep and the intensified portion is determined by the setting of the A TIME/DIV switch and the DELAY-TIME MULTIPLIER dial. The intensified portion is produced by the B sweep. When the HORIZ DISPLAY switch is set to DELAYED SWEEP (B), only the intensified portion, as viewed in the A INTEN DURING B position, is displayed on the screen at the sweep rate determined by the B TIME/DIV switch (see fig. 8-11, B).

B sweep mode. The B sweep mode switch provides two modes of delayed sweep operation. Figure 8-12 illustrates the difference between these two modes. In the B STARTS AFTER DELAY TIME position, the B sweep is presented immediately after the delay time (see fig. 8-12, A). The B sweep is triggered at a selected point on A sweep to provide the delay time (B sweep essentially free-running). Since the delay time is the same for each sweep, the display appears stable. In the TRIGGERABLE AFTER DELAY TIME position, the B sweep operates only when it is triggered (by

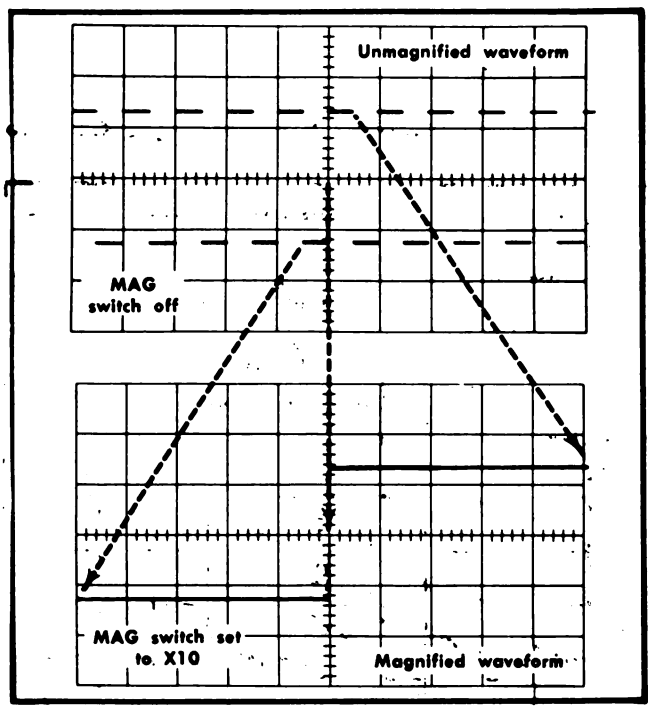

Figure 8-10. Operation of sweep amplifier.

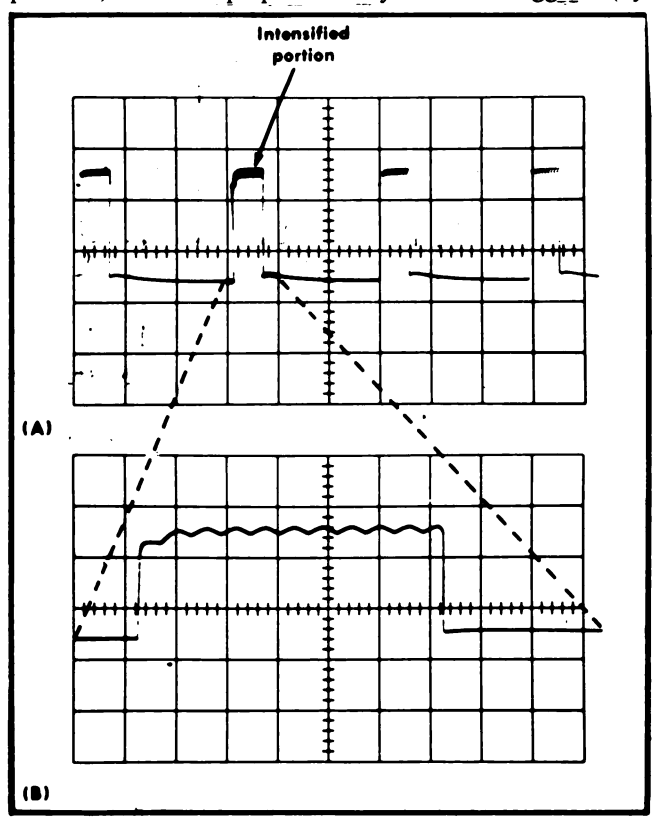

Figure 8-11. Delayed sweep display.

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trigger circuits) after the selected delay time (see fig. 8-12, B). The B triggering controls operate as described in this section.

Delayed sweep operation. To obtain a delayed sweep display, use the following procedure:

a. Obtain a stable display with the HORIZ DISPLAY switch set to A.

b. Set the HORIZ DISPLAY switch to A INTEN DURING B.

c. Set the B SWEEP MODE switch to the desired setting. If TRIGGERABLE AFTER DELAY TIME is selected, correct B triggering is also necessary.

d. Set the delay time with the A TIME/DIV switch and the DELAY-TIME MULTIPLIER dial.

e. Pull the DELAYED SWEEP (B TIME/DIV) knob out, and set to the desired sweep rate.

f. If the TRIGGERABLE AFTER DELAY TIME position is used, check the display for an intensified portion. An absence of the intensified zone indicates that B sweep is not correctly triggered.

g. Set the HORIZ DISPLAY switch to DELAYED SWEEP (B). The intensified zone shown in the A INTEN DURING B position is now displayed at the sweep rate selected by the B TIME/DIV switch.

A sweep length. The A SWEEP LENGTH control is most useful when used with a delayed sweep. As the control is rotated counterclockwise from the FULL position, the length of the A sweep decreases (sweep rate remains constant) until it is about four divisions long in the counterclockwise position (not in B ENDS A detent). The B ENDS A position produces a display that ends immediately following B sweep if the B sweep ends before the normal end of A

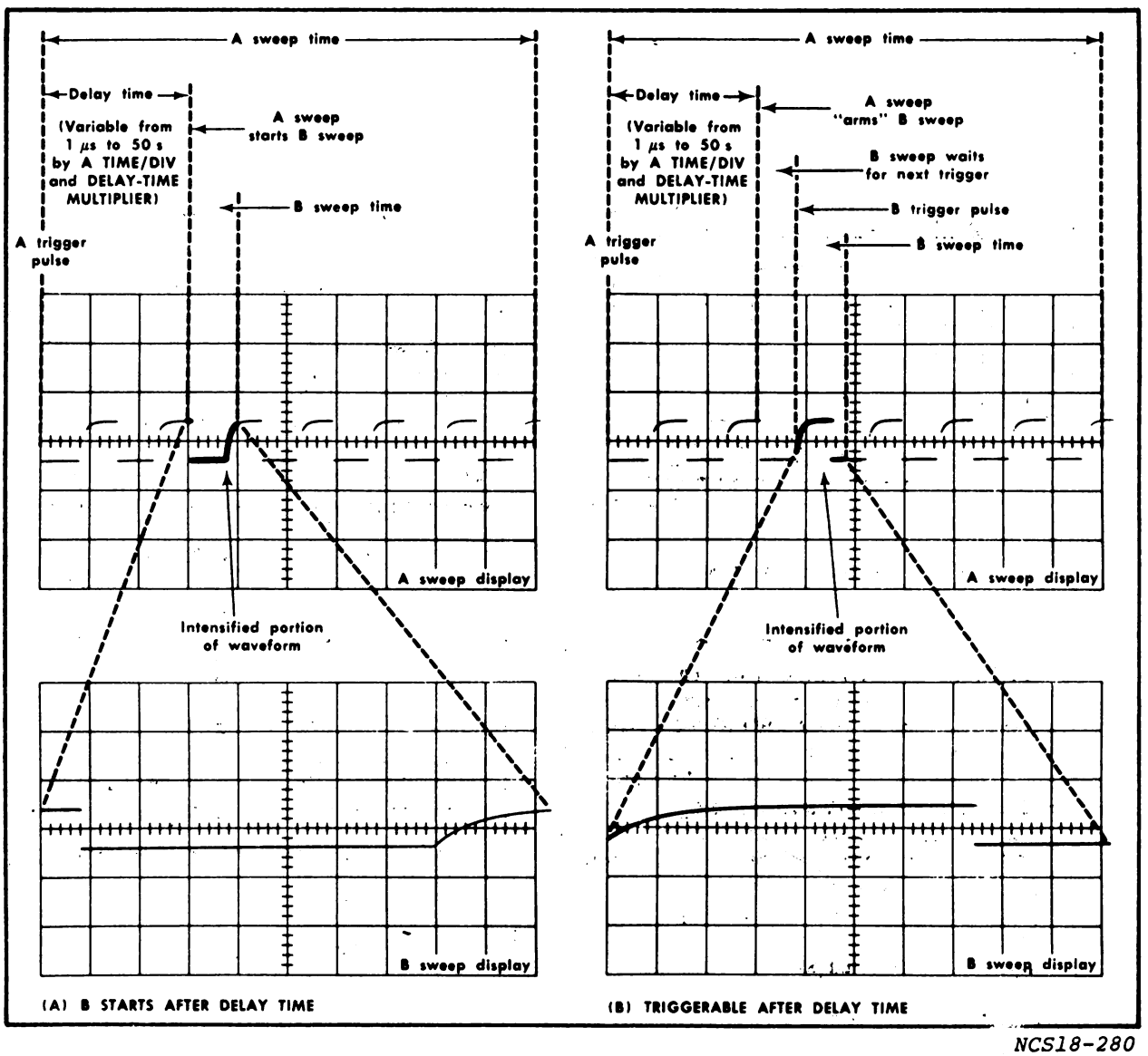
A sweep time
Delay time
(Variable from 1 µs to 50 s by A TIME/DIV and DELAY-TIME MULTIPLIER)
A sweep starts B sweep
B sweep time
A trigger pulse
A sweep display
Intensified portion of waveform
B sweep display
(A) B STARTS AFTER DELAY TIME
A sweep time
Delay time
(Variable from 1 µs to 50 s by A TIME/DIV and DELAY-TIME MULTIPLIER)
A sweep "arms" B sweep
B sweep waits for next trigger
B trigger pulse
B sweep time
A trigger pulse
A sweep display
Intensified portion of waveform
B sweep display
(B) TRIGGERABLE AFTER DELAY TIME
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Figure 8-12. Comparison of the delayed sweep modes.

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sweep. The A SWEEP LENGTH control is used to increase the repetition rate of delayed sweep displays.

To use the A SWEEP LENGTH control, set the HORIZ DISPLAY switch to A INTEN DURING B and set the delay time and delayed sweep rate in the normal way. Turn the A SWEEP LENGTH control counterclockwise until the sweep ends immediately following the intensified portion on the display. Now set the HORIZ DISPLAY switch to DELAYED SWEEP (B). This method provides the maximum repetition rate for a given delayed sweep display. In the B ENDS A position, the maximum delayed sweep repetition rate is maintained automatically.

Exercises (068):

1. Give the frequency range of the Type 453 oscilloscope.

2. What are the positions on the INPUT COUPLING switch

3. State the types of triggering available with the Type 453 oscilloscope.

4. When would it be desirable to use the ALT position of the MODE TRIGGER selector?

5. If you need to view twice as many sine waves as are presently displayed, which control should you use to change the sweep rate? (You are in an undelayed mode without magnification.)

6. If the TIME/DIV switch were on 2 microseconds with the MAG switch set to 10X, calculate what the magnified sweep rate would be.

7. Which controls are responsible for varying the time interval between the start of a sweep and an intensified area of that sweep?

069. Determine the control settings necessary to measure specified voltages, using the Type 453 oscilloscope.

Basic Applications. The Type 453 Tektronix oscilloscope is a versatile piece of equipment. One of its valuable features is its ability to measure voltages.

Peak-to-peak voltage measurements—AC. To make a peak-to-peak voltage measurement, use the following procedure:

(1) Connect the signal to either INPUT connector.
(2) Set the MODE switch to display the channel used.
(3) Set the VOLTS/DIV switch to display about five divisions of the waveform.
(4) Set the INPUT COUPLING switch to AC.

NOTE: For low-frequency signals below about 16 hertz, use the DC position.

(5) Set the A TRIGGERING controls to obtain a stable displays. See the TIME/DIV switch to a position that displays several cycles of the waveform.
(6) Turn the vertical POSITION control so that the lower portion of the waveform coincides with one of the graticule lines below the center horizontal line and the top of the waveform is in the viewing area. Move the display with the horizontal POSITION control so that one of the upper peaks lies near the center vertical line (see fig. 8-13).

(7) Measure the divisions of vertical deflection from peak to peak. Make sure the VARIABLE VOLTS/DIV control is in the CAL position.

NOTE: This technique may also be used to make measurements between two points on the waveform rather than from peak to peak.

(8) Multiply the distance measured in step (7) by the VOLTS/DIV switch setting. Also include the attenuation factor of the probe, if any.

Example: Assume a peak-to-peak vertical deflection of 4.6 divisions (see fig. 8-13) using a 10X attenuator probe and a VOLTS/DIV switch setting of .5.

Using the formula:

Volts peak to peak =vertical deflection (divisions)
×VOLTS/DIV setting
×probe attenuation factor

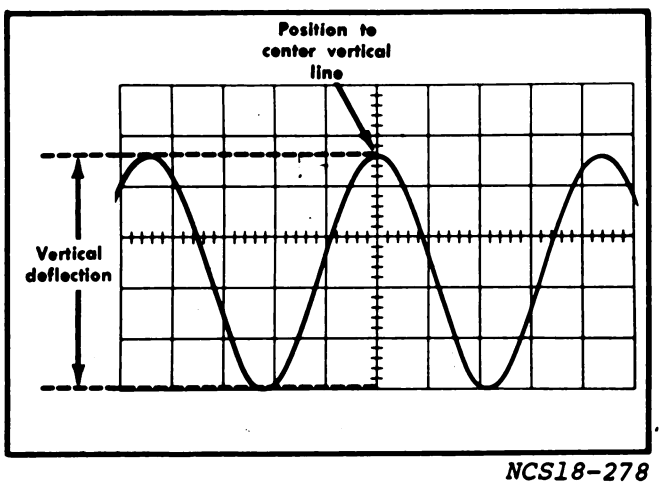

Figure 8-13. Measuring peak-to-peak voltage of a waveform.

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Substituting the given values:

Volts peak to peak =4.6 × 0.5V × 10

The peak-to-peak voltage is 23 volts.

Instantaneous voltage measurements—DC. To measure the DC level at a given point on a waveform, use the following procedure:

(1) Connect the signal to either INPUT connector.
(2) Set the MODE switch to display the channel used.
(3) Set the VOLTS/DIV switch to display about 5 divisions of the wafeform.
(4) Set the INPUT COUPLING switch to GDN.
(5) Set the A SWEEP MODE switch to AUTO TRIG.
(6) Position the trace to the bottom line of the graticule or other reference line. If the voltage is negative with respect to ground, position the trace to the top line of the graticule. Do not move the vertical POSITION control after this reference line has been established.

NOTE: To measure a voltage level with respect to a voltage rather than ground, make the following changes in step (6). Set the INPUT COUPLING switch to DC and apply the reference voltage to the INPUT connector. Then position the trace to the reference line.

(7) Set the INPUT COUPLING switch to DC. You can check the ground reference line at any time by switching to the GND position (except when using a DC reference voltage).
(8) Set the A TRIGGERING controls to obtain a stable display. Set the TIME/DIV switch to a setting that displays several cycles of the signal.
(9) Measure the distance in divisions between the reference line and the point on the waveform at which the DC level is to be measured. For example, in figure 8-14, the measurement is made between the reference line and point A.
(10) Establish the polarity of the signal. If the waveform is above the reference line, the voltage is positive; below the line, negative (when the INVERT switch is pushed in if you are using channel 2).
(11) Multiply the distance measured in step (9) by the VOLTS/DIV switch setting. Include the attenuation factor of the probe, if any.

Example: Assume that the vertical distance measured is 4.6 divisions (see fig. 8-14), the waveform is above the reference line, and you are using a 10X attenuator probe and a VOLTS/DIV setting of 2.

Using the formula:

Instantaneous Voltage=vertical distance (divisions)
×polarity
×VOLTS/DIV setting
×probe attenuation factor

Substituting the given values:

Instantaneous voltage=4.6 × + 1 × 2V × 10

The instantaneous voltage is +92 volts.

Voltage comparison measurements. In some applications, you may need to establish a set of deflection factors other than those indicated by the VOLTS/DIV switch. This is useful for comparing signals to a reference voltage amplitude. To establish a new set of deflection factors based upon a specific reference amplitude, proceed as follows:

(1) Apply the reference signal of known amplitude to either INPUT connector. Set the MODE switch to display the channel used. Using the VOLTS/DIV switch and the VARIABLE control, adjust the display for an exact number of divisions. Do not move the VARIABLE VOLTS/DIV control after obtaining the desired deflection.
(2) Divide the amplitude of the reference signal (volts) by the product of the deflection in divisions (established in step (1)) and the VOLTS/DIV switch setting. The result is the deflection conversion factor.

$$\text{Deflection conversion factor} = \frac{\text{reference signal amplitude (volts)}}{\text{deflection (divisions)} \times \text{VOLTS/DIV setting}}$$

(3) To establish an adjusted deflection factor at any setting of the VOLTS/DIV switch, multiply the VOLTS/DIV switch setting by the deflection conversion factor established in step (2).

Adjusted deflection factor = VOLTS/DIV setting × deflection conversion factor

This adjusted deflection factor applies only to the channel used and is correct only if the VARIABLE VOLTS/DIV control is not moved from the position in step (1).
(4) To determine the peak-to-peak amplitude of a signal compared to a reference, disconnect the reference and apply the signal to the INPUT connector.
(5) Set the VOLTS/DIV switch to a setting that will provide enough deflection to make the measurement. Do not readjust the VARIABLE VOLTS/DIV control.

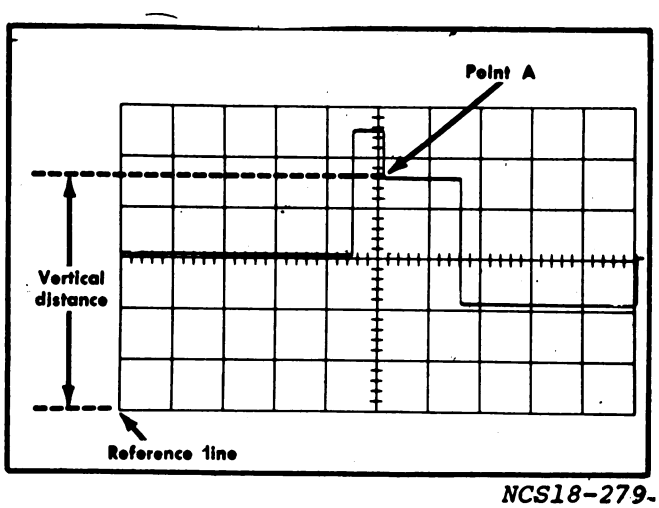

Figure 8-14. Measuring instantaneous DC voltage with respect to a reference.

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(6) Measure the vertical deflection in divisions and determine the amplitude by the following formula:

Signal amplitude = adjusted deflection factor × deflection (divisions)

Example: Assume a reference signal amplitude of 30 volts, a VOLTS/DIV setting of 5 and a deflection of 4 divisions. Substituting these values in the deflection conversion factor formula (step (2)):

$$\text{Deflection conversion factor} = \frac{30\text{V}}{4 \times 5\text{V}} = 1.5$$

Then, with a VOLTS/DIV switch setting of 10, the adjusted deflection factor (step (3)) is:

Adjusted deflection factor = 10V × 1.5 = 15 volts/division

To determine the peak-to-peak amplitude of an applied signal that produces a vertical deflection of 5 divisions, use the signal amplitude formula (step (6)):

Signal amplitude = 15V × 5 = 75 volts

Exercises (069):

1. What voltage checks or measurements can you make with the Type 453 oscilloscope?

2. With a reference signal amplitude of 20 volts, a VOLTS/DIV setting of 2, and a deflection of 5 divisions, what is the deflection conversion factor?

3. When checking a waveform with a 10× probe and the VOLTS/DIV setting on 5, you find that the waveform covers 3.5 divisions above the reference line. What is the instantaneous voltage?

4. In checking an AC voltage for peak-to-peak measurement, what position must the VARIABLE VOLTS/DIV control be in?

5. What is the peak-to-peak voltage of a signal with a display of 5.4 vertical divisions, a VOLTS/DIV setting of 2, and a probe attenuation of 20?

070. Describe the results of selected control positions for making time and frequency measurement using the Type 453 oscilloscope and, given specific data, solve for time duration and frequency.

Time and Frequency Measurements. Time and frequency measurements comprise a large percentage of oscilloscope usage. They constitute the basis for determining most equipment malfunctions. Learning how to interpret the oscilloscope display should have high priority on your training schedule.

Time duration measurements. The waveforms that are most often measured are square waves, sine waves, and triggers. Very rarely are the more complex patterns, such as Lissajous figures, viewed. Proper positioning of the waveform under inspection is paramount because there may be some distortion or nonlinearity of the sweep speed. Because of this, it is desirable to measure only that part of the waveshape beginning 1 division from the edge of the graticule. The graticule is the plastic overlay upon which a grid is etched for reference purposes. Figure 8-15 shows the grid over the CRT face with a sine wave displayed.

The vertical amplitude is set by the VOLTS/DIV switch for about 5 divisions. Sweep stabilization is achieved with the A TRIGGERING controls. The sweep speed (set by the TIME/DIV switch) must contain the desired waveform within 8 divisions on the grid. Positioning the waveform is a function of the VERT POSITION and HORIZ POSITION controls. The beginning of the waveshape is placed at a reference point on the grid and the number of horizontal divisions is counted to the second time reference point. Be sure that the A VARIABLE control is in the CAL position; otherwise the TIME/DIV switch will not be accurate. A simple multiplication of the TIME/DIV switch sweep-speed position by the number of grid divisions determines the time between the grid reference points. If the MAGNIFIER switch is ON, the product must be divided by 10.

Example 1: Assume that the difference between the time measurement points is 7 divisions (see fig. 8-15) and the TIME/DIV switch is set at 50 microseconds with the MAGNIFIER at X10.

Using the formula:

$$\text{Time duration} = \frac{\text{Horizontal distance (divisions)} \times \text{TIME/DIV setting}}{\text{magnification}}$$

Substitute the given values:

$$\text{Time duration} = \frac{7 \times 50\mu\text{sec}}{10}$$

Time duration = 35 microseconds

Frequency measurements. The procedure we used in determining time duration can also be used to measure the frequency of a periodically recurring waveshape. From your basic electronic training, you should remember that frequency is the reciprocal of time. Assuming that the entire sine wave falls within 7 grid divisions and the sweep speed remains the same as in example 1, the formula becomes:

$$\text{Frequency} = \frac{1}{\text{time duration}} = \frac{1}{35\ \mu\text{sec}} = 28.571\ \text{kHz}$$

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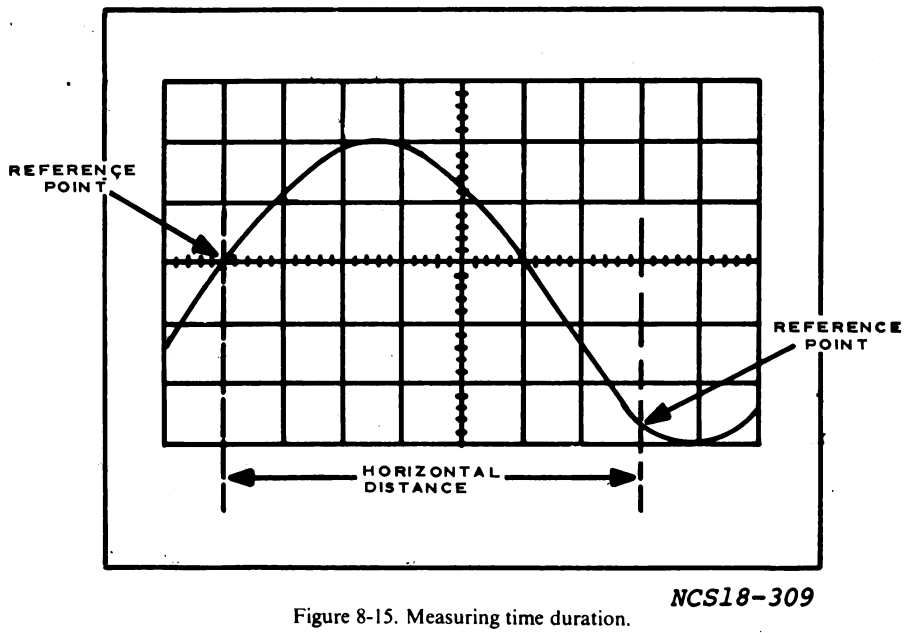

Figure 8-15. Measuring time duration.

Rise-time measurements. Another consideration you have to make in diagnosing malfunctions is that of the rise time and fall time of a particular signal. This factor becomes very important in dealing with high-speed digital switches. Generally, the area under measurement is within the 10-to 90-percent points of the rise time. Fall time is measured the same way except the trailing edge of the waveform is measured.

The sweep of the waveform under test must be established so that the 10- and 90-percent points of the waveform fall within the innermost 8 divisions. The TIME/DIV control is used for this procedure.

Determine the 10- and 90-percent points on the rising portion of the waveform, as shown in figure 8-16. Place the 10-percent points at the first grid line and count horizontally to the grid line that intersects the 90-percent point of the waveform. Using the time duration formula, you may now determine the rise time of a given signal.

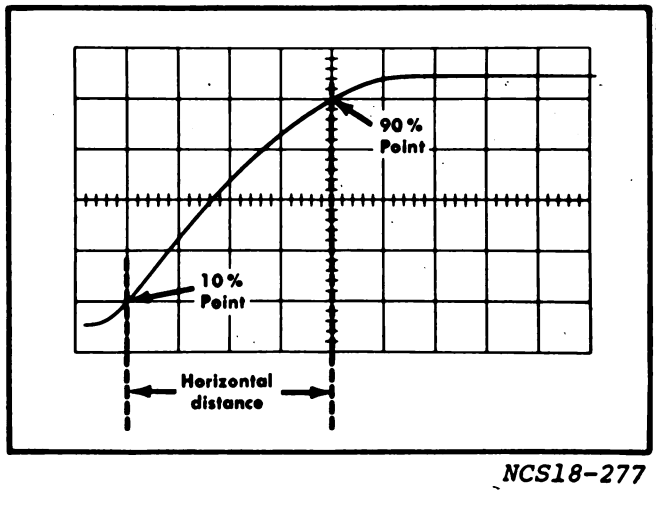

Figure 8-16. Measuring rise time.

Example 2: Assume that the horizontal distance between the 10- and 90-percent points is 4 divisions (fig. 8-16) and the TIME/DIV switch is set to 5 microseconds with the MAGNIFIER switch set to X10.

Substituting the given values in the formula for time duration, the equation becomes:

$$\text{Rise time} = \frac{4 \times 5\ \mu\text{sec}}{10} = 2 \text{ microseconds}$$

Time-difference measurements. The dual-trace capability of the Type 453 oscilloscope lends itself to measuring differences in time between two signals. Normally, the reference signal precedes the comparison signal in time. Refer to figure 8-17. The dual-trace presentations are set for the same polarity, a vertical display of 4 to 5 divisions, and a sweep speed that separates the signal reference points by 3 or more divisions. POSITION controls center each waveform. Emphasis is placed upon using the HORIZ POSITION control to have the reference waveform cross the center horizontal line at a vertical grid line. The time difference between the two reference points can easily be measured.

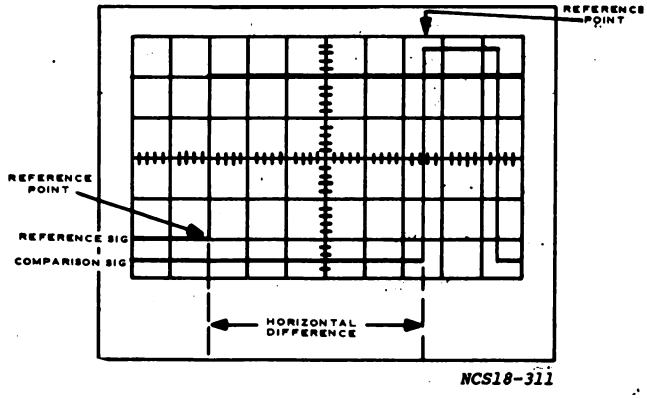

Figure 8-17. Measuring time difference between two signals.

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Example: Assume that the TIME/DIV switch is set to 20 microseconds , the MAGNIFIER switch to N10, and the horizontal difference between the waveform reference points is 5.5 divisions.

$$\text{Time difference} = \frac{\text{TIME/DIV setting} \times \text{horizontal difference (divisions)}}{\text{magnification}}$$

Substituting the given values:

$$\text{Time difference} = \frac{20\ \mu\text{sec} \times 5.5}{10}$$

Time difference = 11 microseconds

Exercises (070):

1. What effect does the MAG X10 switch have on the sweep speed?

2. What is the effect of positioning a waveform too close to the edge of the CRT?

3. The TIME/DIV switch is accurate only if the A VARIABLE control is in the _____ position.
4. Given a positive square wave with 6 grid divisions between the reference points, find the time duration of the area under inspection when the TIME/DIV switch is on 50 microseconds and the MAG switch is off.

5. Solve for the frequency when the TIME/DIV switch is on 1 ms and the sine wave covers 6 horizontal divisions on the grid. The MAG switch is on X10.

6. The rise time of a signal is supposed to be .33 microsecond. The MAG switch is on X10 position. The 10- and 90-percent points fall 3 divisions apart. When will the TIME/DIV switch be set to view the signal under these conditions?

7. Describe the positioning of a reference signal on the CRT when the time relationship is being compared to another signal.

071. Outline the procedure for determining the time difference between two pulses, using the delayed sweep feature of the Type 453 oscilloscope and, given specific data, determine time differences and control settings.

Displaying Complex Signals Using the Delayed Sweep. Accurate time measurements can be made using the delayed sweep mode. This is the mode to use to find the time difference between two pulses displayed on the same trace. You can also measure the time difference from two different sources (dual-trace) or the time duration of a single pulse.

Delayed sweep time measurements. We will discuss the fundamental procedures in setting up the oscilloscope for this mode of operation. Initial sweep settings establish an amplitude of about 4 divisions, and the sweep speed contains the entire area of interest within 8 horizontal divisions. Set the A TIME/DIV switch to A INTEN DURING B and the B SWEEP MODE switch to B STARTS AFTER DELAY TIME. The B TIME/DIV switch should be set at 1/100 of the A TIME/DIV sweep rate, producing an intensified portion of about 0.1 division in length. The intensified portion can be moved along the trace by the DELAY-TIME MULTIPLIER dial. Adjust the dial until the pulse or signal starts at one of the vertical grid lines on the graticule; note the dial reading. Now, turn the dial until the second pulse appears at the same position as the first. Again note the dial reading. Subtract the first dial setting from the second, and multiply the result by the delay time shown by the A TIME/DIV switch. This is the time interval between pulses.

Example: Assume that the first dial setting is 1.31, and the second dial setting is 8.81 with the A TIME/DIV switch set to 0.2 microsecond (see fig. 8-18).

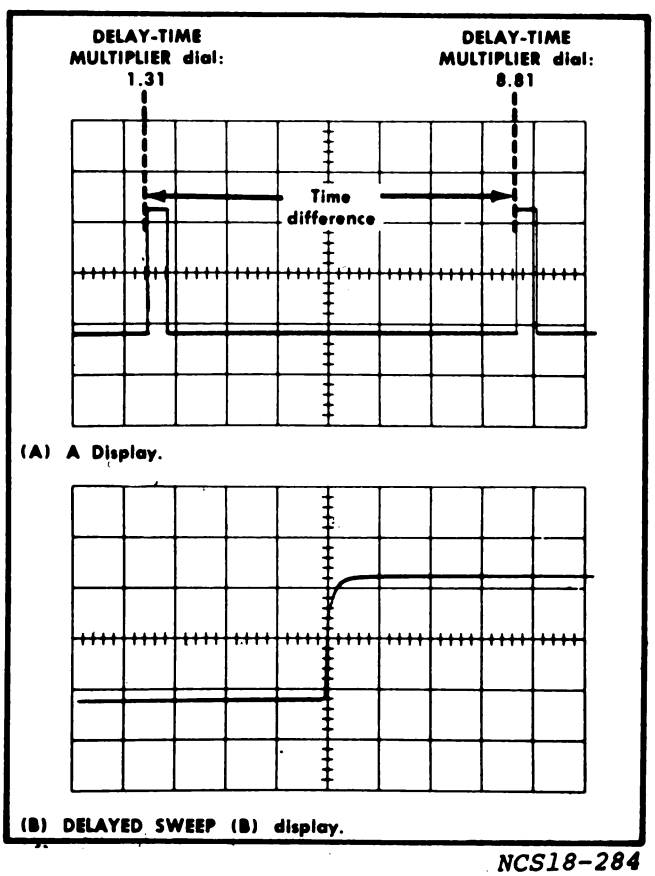

Figure 8-18. Measuring time difference using delayed sweep.

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Time difference (delayed sweep) =(second dial setting – first dial setting) X delay time (A TIME/DIV setting)

Substituting the given values:

Time difference =(8.81 - 1.31) X 0.2 microsecond
Time difference =1.5 microsecond

Delayed sweep magnification. The delayed sweep feature of the Type 453 can provide higher apparent magnification than is provided by the MAG switch. The sweep rate of the DELAYED SWEEP (B sweep) is not actually increased. The apparent magnification is the result of delaying the B sweep for an amount of time selected by the A TIME/DIV switch and the DELAY-TIME MULTIPLIER dial before the display is presented at the sweep rate selected by the B TIME/DIV switch. The following steps use the B STARTS AFTER DELAY-TIME position to allow the delayed portion to be positioned with the DELAY-TIME MULTIPLIER dial. The display is established showing about 4 divisions of amplitude with a sweep rate that shows the complete waveform.

Follow the next steps:

(1) Set the HORIZ DISPLAY switch to A INTEN DURING B and the B SWEEP MODE switch to B STARTS AFTER DELAY TIME.

(2) Position the start of the intensified portion with the DELAY-TIME MULTIPLIER dial to the part of the display to be magnified.

(3) Set the B TIME/DIV switch to a setting that intensifies the full portion to be magnified. The start of the intensified trace remains as positioned in step (2).

(4) Set the HORIZ DISPLAY switch to DELAYED SWEEP (B). Time measurements can be made in the conventional manner. The sweep rate is determined by the setting of the B TIME/DIV switch.

You can calculate the apparent sweep magnification by dividing the A TIME/DIV switch by the B TIME/DIV switch setting.

Example: The apparent magnification of the display shown in figure 8-19 with an A TIME/DIV switch setting of .1 ms and a B TIME/DIV switch setting of 1 microsecond is:

$$\textit{Apparent magnification} = \frac{\textit{A TIME/DIV setting}}{\textit{B TIME/DIV setting}}$$

Substituting the given values:

$$\text{Apparent magnification} = \frac{1 \times 10^{-4}}{1 \times 10^{-6}}$$

The apparent magnification is 100 times.

Triggered delayed sweep magnification. The method of producing a sweep that we have just described may produce too much jitter at high-apparent magnification ranges. The TRIGGERABLE AFTER DELAY TIME position of the B SWEEP MODE switch provides a more stable display because the delayed display is triggered at the same point each time. After the sweep has been established on the scope, as described in the previous paragraphs, the B TIME/DIV switch is set to intensify the full portion to be magnified. Move the B SWEEP MODE switch to TRIGGERABLE AFTER DELAY TIME and adjust the B LEVEL control so the intensified portion of the trace is stable. If you cannot intensify the desired portion, you may not have the B TRIGGERING controls properly set or the signal does not meet the triggering amplitude requirements. If the condition cannot be remedied with the B TRIGGERING controls or with an increase in the display amplitude (lower VOLTS/DIV setting), you should trigger B sweep externally. When the correct portion is intensified, set the HORIZ DISPLAY switch to DELAYED SWEEP (B) and readjust the B LEVEL control for a stable display.

Pulse jitter measurements. In some cases, it is necessary to measure the amount of jitter on the leading edge of a pulse, or the jitter between pulses. The technique involves establishing a stable sweep and intensifying the area to be inspected. The HORIZ DISPLAY switch displays only the intensified portion when it is placed in the DELAYED SWEEP (B). Pulse jitter is shown by the horizontal movement of the pulse, shown in figure 8-20. Take into account the inherent jitter of the delayed sweep. Measure the amount of horizontal movement and multiply this distance by the B TIME/DIV switch setting to obtain the pulse jitter in time.

Example: Assume that the horizontal movement is 0.5 divisions (fig. 8-20) an the B TIME/DIV switch setting is 0.5 microseconds.

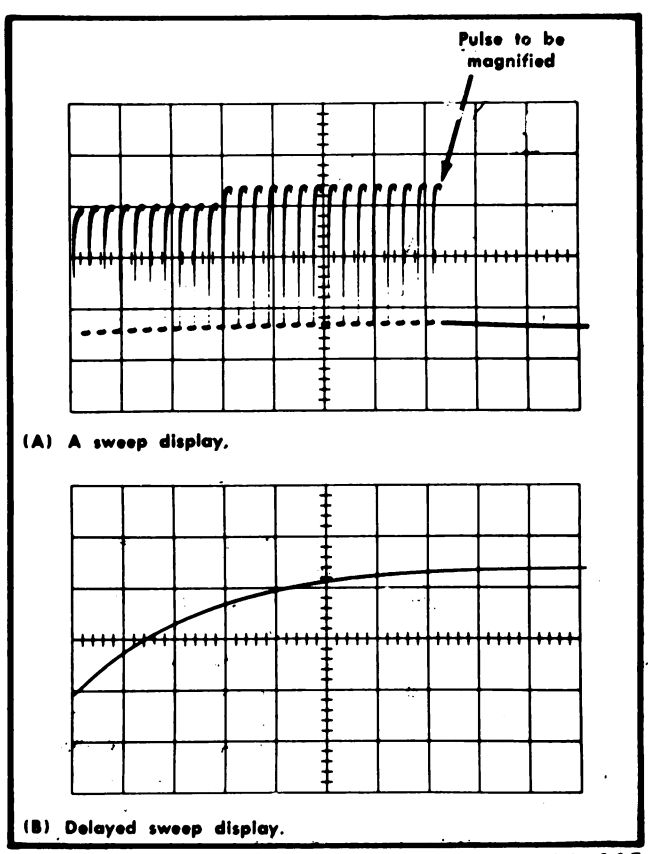

Figure 8-19. Using delayed sweep for sweep magnification.

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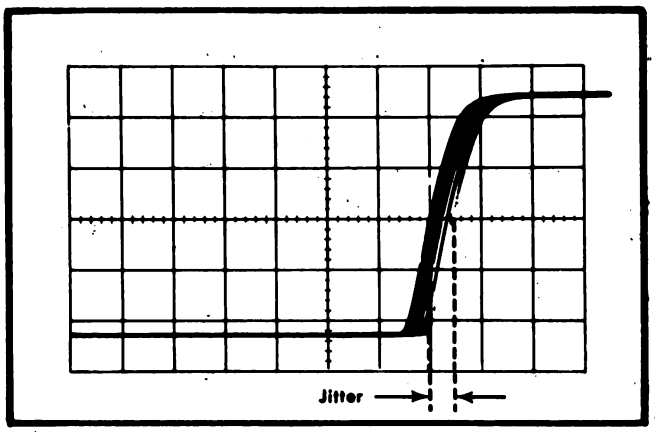

Figure 8-20. Measuring pulse jitter.

Using formula:

Pulse Jitter = Horizontal jitter (division) × B TIME/DIV setting

Substituting the given value:

Pulse jitter = 0.5 X 0.5 μsec = 0.25 μsec

Complex signal display. Complex signals often consist of a number of individual events of differing amplitudes. Since the trigger circuits are sensitive to changes in signal amplitude, a stable display can normally be obtained only when the sweep is triggered by the event with the greatest amplitude. However, this may not produce the desired display of a lower amplitude signal that follows the triggering event. Since the delayed sweep feature does provide a means of delaying the start of the B sweep by a selected amount, the part of the waveform that contains the information of interest can be displayed. Figure 8-21 shows a complex waveform as displayed on the CRT. The circled portion cannot be viewed in any greater detail, because the sweep is triggered by the larger amplitude pulses at the start of the display and a faster sweep rate moves this area of the waveform off the viewing area. The second waveform shows the area of interest magnified 10 times using delayed sweep. The DELAY-TIME MULTIPLIER dial has been adjusted so that the delayed sweep starts just before the area of interest.

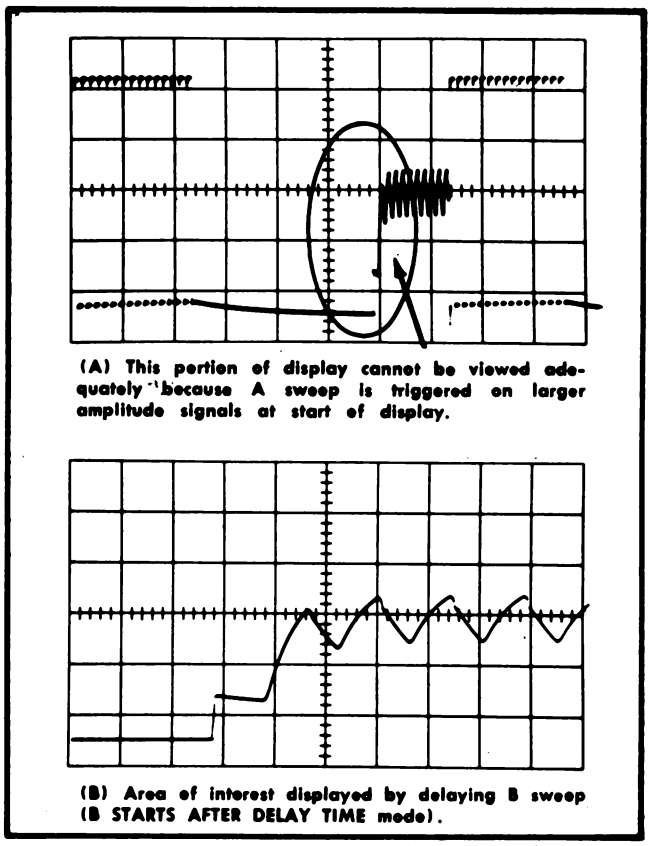
(A) This portion of display cannot be viewed adequately because A sweep is triggered on larger amplitude signals at start of display.
(B) Area of interest displayed by delaying B sweep (B STARTS AFTER DELAY TIME mode).
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Figure 8-21. Displaying a complex signal using delayed sweep.

Exercises (071):

1. Describe the procedure for determining the time interval between two pulses, using the delayed sweep time method.

2. Find the time difference between two pulses. The first pulse is noted at a dial setting of 2.35 on the DELAY-TIME MULTIPLIER dial. The second pulse comes at 7.45. The A TIME/DIV switch is on 0.1 ms.

3. Determine the apparent magnification of a display from the following conditions: The A TIME/DIV switch is on 1 ms and the B TIME/DIV switch is on 5 microseconds.

4. Reference figure 8-19. To gain an apparent magnification of 250, what must the A TIME/DIV switch setting be when the B TIME/DIV setting is on 2 microseconds?

5. Reference figure 8-20. Pulse jitter movement occupies .75 horizontal divisions on the grid and the B TIME/DIV switch setting is 2 microseconds. What is the pulse jitter in terms of time?

8.5 Vacuum-Tube Tester

The vacuum-tube tester is a necessary item of test equipment widely used in the testing and repair of electronic equipment. Since many electronic malfunctions are due to weak or faulty vacuum tubes, the tester enables the maintenance mechanic to detect tubes that are too weak for suitable operation in the prime equipment as well as to determine whether the tube is causing the entire malfunction of the system. If the average receiving tube is not overdriven or operated continuously at maximum rating, it can be ex-

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pected to have a life of at least 2,000 hours before the filament opens. However, the contraction and expansion of the tube elements during heating and cooling can cause the elements to sag or lean. This condition increases the possibility of voltage arcs between the elements and decreases the coating on the emitter, which decreases conduction.

072. Describe key features of the different tests available with the dynamic-type tube tester.

Basic Vacuum-Tube Tester Theory. There are two types of tests used to evaluate the condition of a vacuum tube—*static* and *dynamic.* In the static method of testing, the condition of the vacuum tube is determined by setting in stepped voltages and currents to the tube elements. This type of test is not always conclusive as it does not check the tube under actual operating conditions. The dynamic type of test checks the vacuum tube under conditions similar to the actual operation in the electronic circuit. The vacuum-tube tester discussed in this section is a dynamic type.

Vacuum-Tube Tests. The tests normally made with the dynamic-type tube tester are the emission test, mutual conductance test, short test, noise test, gas test, and cathode leakage test. We shall discuss each of these tests briefly.

Emission test. An important evaluation of the tube's condition is obtained by a check of the cathode or filament emission. Usually, the loss of emission or a noticeable decrease in emission indicates that the tube is reaching the end of its normal life span.

When you are making the emission test of multigrid tubes, the grids are connected to the plate, as shown in figure 8-22. A current meter and rheostat are placed in series with the tube, which is connected across the secondary of the transformer. Since the plate and grids are common tie points, they are at the same potential in respect to the cathode. The tube then acts as a diode rectifier that conducts only on alternate half-cycles when the plate is positive in respect to the cathode. The meter measures the amount of current that flows through the tube, thus indicating the condition of the cathode emitting surface. The meter face in the tube tester is divided into three areas: (1) good, (2) weak or fair, and (3) bad. Set the variable resistance to a predetermined value, according to the instructions supplied with the test set, to prevent overloading the meter. Diode tubes can be tested in the same way to determine the quality of their emitters.

Mutual conductance test. The term "mutual conductance" (or transconductance) expresses the effect of grid voltage upon the plate current of a tube. Because it simulates actual circuit conditions, the mutual conductance test evaluates the tube more accurately than the cathode emission test does. The unit of measurement in dealing with conductance is the mho. The readings are expressed in micromhos since they are so small.

As shown in figure 8-23, the dynamic method of determining mutual conductance uses a circuit that applies an AC signal to the control grid of the tube under test, in addition to a fixed bias. The tube under test serves as a load to the rectifier circuit. With a fixed bias, represented by E_G, applied to the control grid, the circuit acts as a simple full-wave rectifier. When the AC signal is positive at P1, there is current flow through R1, and the meter pointer attempts to deflect in one direction. Then the AC signal reverses and P2 becomes positive. The current flows through R2, and the meter pointer tends to swing in the opposite direction. Since these changes are at a 60-Hz rate, the meter pointer remains at zero.

In addition to the fixed DC bias applied to the control grid, an AC signal from the secondary of the transformer is also applied. When this AC signal is positive at the same time that the signal is positive at P1, the meter pointer will swing more in one direction than normal. When the AC signal is positive at P2, the AC signal on the control grid is negative and the tube under test does not conduct. With P2 positive, the current flow through the meter movement tends to direct the meter pointer in the opposite direction. However, since the pointer was farther in the other direction than normal, the canceling effect does not bring it back to zero. Therefore, the meter reading indicates the amount of change in plate current caused by a change in control grid voltage under dynamic conditions. Any deviation from the rated or normal amount of mutual conductance for a specific type of tube indicates either a defective or deteriorated tube. The meter is calibrated in terms of good, weak, and bad, or it is scaled directly in micromhos.

Short test and noise test. Because it shows any shorts between elements, the short test is usually one of the first steps in checking any tube. By making this test first, you

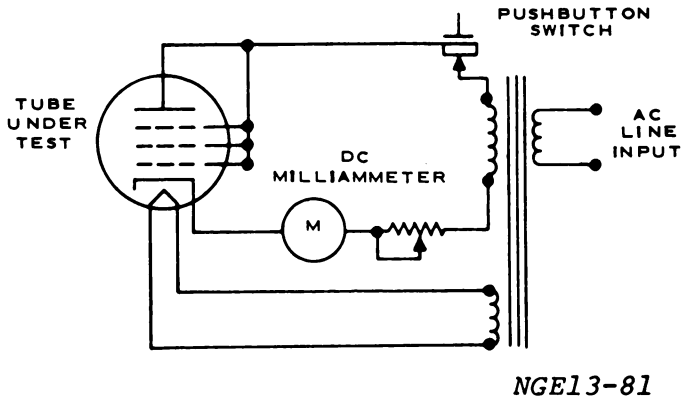

Figure 8-22. Basic emission test circuit.

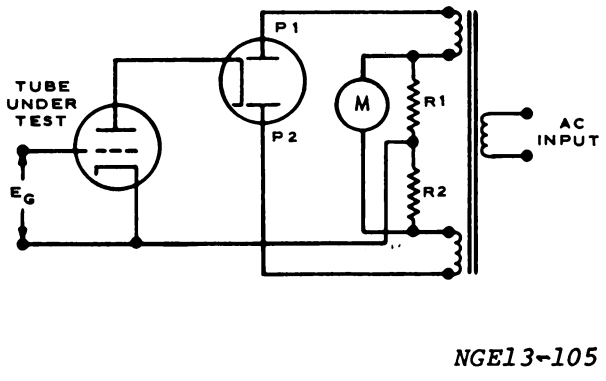

Figure 8-23. Basic dynamic mutual conductance test circuit.

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protect the meter from being overloaded during other tests. A short-circuit test is usually sensitive enough to indicate a resistance leakage of less than one-fourth of a megohm, and the heater voltage is applied so that any tube elements that might short during normal operation will be detected. If the tube is shorted, further testing of the tube is unnecessary.

Figure 8-24 shows the basic circuit used for the short test. In the schematic, the plate switch is in position 2 and all other switches are in position 1. If the plate element is touching any other element within the tube, the AC circuit in the secondary of the transformer will be complete and both plates of the neon lamp will glow. If none of the elements are shorted to the plate, only one plate of the neon lamp will glow. You can switch each element into the circuit and individually check it for a short to other elements. R2 limits the current through the lamp to a safe value. R1 bypasses any small alternating currents in the circuit that might be caused by stray capacitance preventing the neon lamp from indicating erroneously.

The noise test is nothing more than a very sensitive short test. A high-gain amplifier or headset can be connected to the jacks on both sides of the neon lamp. If an amplifier is used, the antenna is connected to one jack and the ground terminal of the receiver connected to the other. If the tube elements are loose, you can hear noise or static from the headset or amplifier speaker. You can also use an AC output meter to check for noise by placing the two leads into the noise test jacks.

Gas test. The presence of gas in most tubes is undesirable. When gas is present, the electrons emitted by the cathode collide with the molecules of gas. This action dislodges electrons from the gas molecules, and positive gas ions are formed. These ions are attracted by the control grid of the tube. Because the control grid is negative, the ions absorb electrons from the grid circuit in order to revert to more stable gas molecules. If the gas in the tube is appreciable, the collisions between the gas molecules and the cathode-emitted electrons release many secondarily-emitted electrons, and the resulting flow of grid current is high.

The gas test indicates whether or not excessive gas is present in the tube. The basic circuit used for the test is shown in figure 8-25. With switch S1 set to position 1, a certain amount of plate current is measured by the DC milliammeter. If the amount of gas in the tube is normal for that tube type, the meter reading will not change when the switch S1 is placed in position 2. If more than the normal amount of gas is present in the tube, current flows through the grid resistor, causing a voltage drop with the polarity as shown. The effect reduces the negative bias voltage on the control grid, allowing the tube to conduct harder and increase plate current. Small increases are normal and large increases indicate the presence of gas.

Cathode leakage test. The cathode of the tube is an important element because it supplies the electrons needed for tube operation. The heater is usually a tungsten alloy wire, inclosed in, but insulated from, the tubular metal cathode sleeve. The cathode is coated with a strontium or barium compound that emits electrons when it is heated. The heater must be placed as close as possible to the walls of the cathode to allow maximum heat exchange. Continuous heating and cooling sometimes causes the insulation to become brittle and cracked. This condition develops into a high-resistance leak between the elements and causes the tube to become noisy and the emission rate to decrease.

The cathode leakage test measures the amount of leakage, if any, between the cathode and the heater elements. It is often made in conjunction with the short test, though some tube testers are designed to make this test as a separate operation.

Figure 8-26 shows the basic circuit that is often used to make the cathode leakage test. With switch S1 in position 2, a certain amount of plate current flows. With the switch in position 1, the cathode becomes a floating element. If there is no leakage between the elements, the meter reading is zero. If the elements are shorted, the plate current reading will be the same as it was with the switch in position 2. Any slight meter reading indicates that a certain number of leakage is taking place.

Use in Field. To be of practical use to the technician in the field, a tube tester must evaluate the quality of a tube quickly and accurately and with a minimum effort on the part of the operator. In order to save time and effort, accuracy is sacrificed to some extent. Field-type tube testers cannot accurately evaluate the function of the tube in its operational circuit. Often a tube that checks out all right in the tester does not operate efficiently in its operational circuit

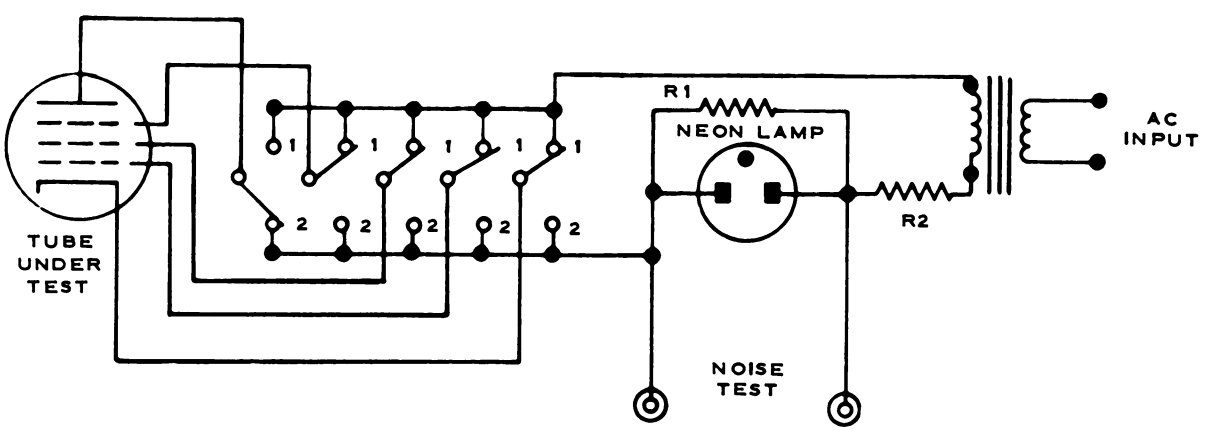

Figure 8-24. Basic circuit for short and noise test.

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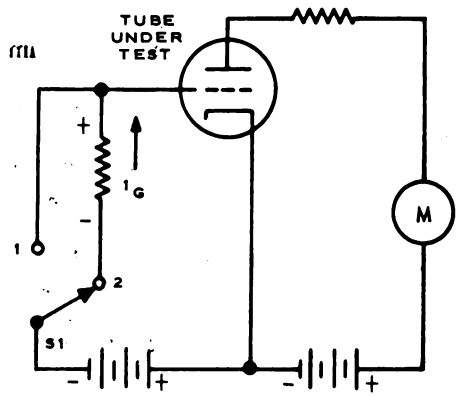

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Figure 8-25. Basic gas test circuit.

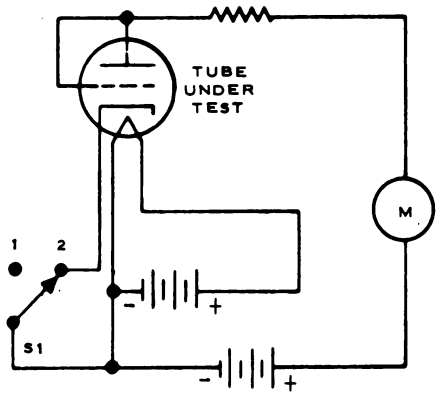

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Figure 8-26. Basic cathode leakage test circuit.

because of the critical characteristics of the circuit. When this occurs, you must place other tubes of the same type in the circuit one at a time until you find one, with the proper characteristics, that functions correctly.

Exercises (072):

1. Normally, what does a noticeable decrease of cathode emission in a vacuum tube indicate?

2. The mutual conductance test evaluates a vacuum tube more accurately than does the cathode emission test. True/False
3. In the dynamic method of determining mutual conductance, the meter may be calibrated in terms of good, weak, and bad. True/False
4. The noise test is only a very sensitive short test. True/False
5. How is a vacuum tube affected by a high-resistance leak between its elements?

6. What action should you take if a tube checks out all right in the tester but does not operate efficiently in its operational circuit?

073. Point out important features of the TV-7/U tube tester.

Electron Tube Test Set, TV-7/U. This test set is a portable tester of the dynamic mutual conductance type and is rugged enough for shop and field work. It can measure performance capabilities and determine the rejection limits for the electron tubes used in receivers, low-power transmitters, and many other electronic devices.

Figure 8-27 shows the TV-7/U test set in detail. The characteristics of the TV-7/U are as follows:

- Meter range—0 to 120 arbitrary units.
- Voltage—115 volts AC, ± 10 percent.
- Frequency—50 to 1,000 Hz.
- Power—115 volts at 45 watts, 50 Hz.

The operating controls of the TV-7/U and their functions are:

a. POWER switch—This on-off switch applies primary power to the test set.

b. LINE ADJUST control—This controls the input to the power transformer. The LINE ADJ button is depressed and the LINE ADJUST control varied until the meter reads on the indicated line on the meter face.

c. GRID, PLATE, SCREEN, CATHODE, SUPPRESSOR, and FILAMENT switches—These rotary selector switches connect the various tube elements to the correct voltages to conduct the desired test. You can determine the position of these switches for a specific tube under test by referring to the information provided in the Tube Test Data Chart.

d. FILAMENT VOLTAGE switch—This selector switch provides filament voltages from 0.6 to 117 volts in 18 steps to the specific tube under test. The BLST position is used when you are testing ballast tubes.

e. BIAS control—This controls the bias on the tube under test.

f. SHUNT control—This controls the sensitivity of the meter circuit when the FUNCTION switch is in the "A" position.

g. FUNCTION switch—This switch selects the proper meter range for the tube under test in positions "A" through "E." In the SHORTS position (1 through 5), the switch connects various elements of the tube under test to the short-indicating circuit.

h. LINE ADJ button—You depress this switch to set the AC line adjustment.

i. MUT COND button—You depress this switch only when you are checking amplifier tubes.

j. DIODE button—This switch is used to check low-power rectifiers similar to those used for second detectors.

k. GAS 1 and GAS 2 buttons—You depress these switches to make the gas test.

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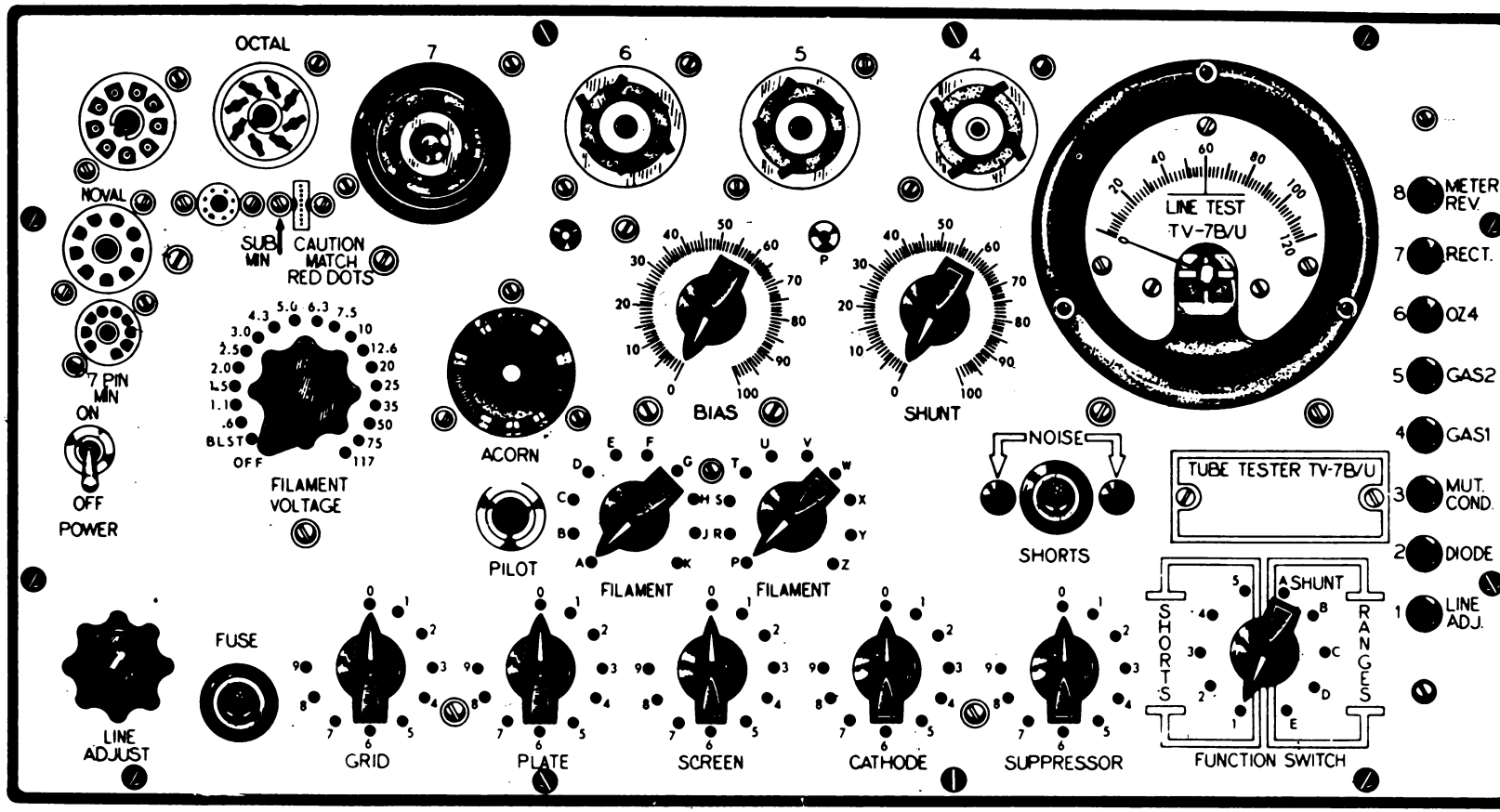

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Figure 8-27. Electron tube test set, TV-7/U.

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l. 0Z4 button—Depress this switch when you are testing cold cathode rectifier tubes, such as type OZ4.

m. RECT button—You depress this switch to test the rectifier tubes used in power supplies.

n. METER REV button—You depress this button to reverse the polarity of the meter when you are testing certain tubes in accordance with the instructions in the Tube Test Data Chart.

o. G jack—This is the tip jack to which the grid caps are connected.

p. P jack—This is the tip jack to which the plate caps are connected.

q. NOISE jacks—These jacks are used with an amplifier or headset to test for noise within the tube under test.

r. Meter (not labeled)—The meter indicates the tube condition on an arbitrary scale. The A LINE TEST mark at midscale establishes the correct AC line input voltage when the LINE ADJ button is depressed and the LINE ADJUST control is properly set.

s. PILOT lamp—This lamp indicates when the POWER switch is ON.

t. NEON lamp (not labeled)—This lamp indicates shorts within the tube under test when the FUNCTION switch is in positions 1 through 5.

u. FUSE lamp—This lamp serves as a protective fuse and as an overload indicator.

Exercises (073):

1. What type of tube tester is the TV-7/U electron tube test set?

2. When should you depress the RECT button on the TV-7/U test set?

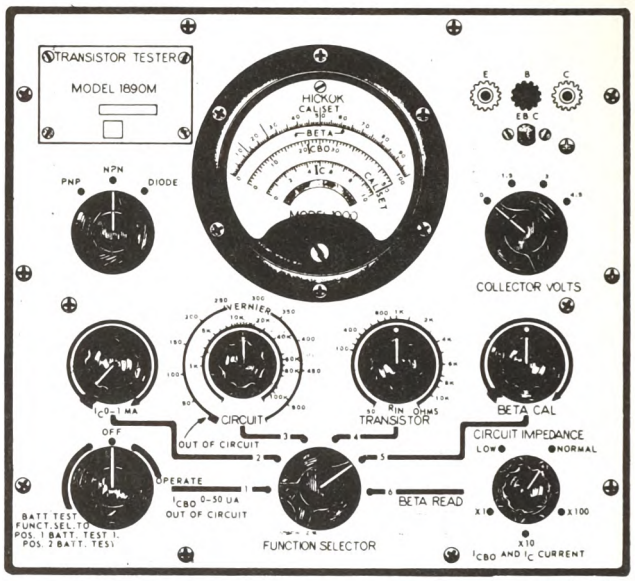
3. Variances in AC line voltage are compensated for by which control on the TV-7/U?

8-6. Transistor Tester

This piece of test equipment is a very useful machine. Unfortunately, not enough technicians understand its operation and frequently it merely collects dust sitting on a shelf.

074. State the purpose of the Model 1890M Transistor Tester, the number of its circuits, and a selected characteristic tested.

The in-circuit-type transistor tester, Model 1890M (fig. 8-28), is designed to test all small and medium power transistors and diodes directly in or out of their circuits. A portable aluminum case houses the complete equipment. Access to the control panel is provided by the detachable top case in which the test lead assembly is stored.



NGE13-2

Figure 8-28. In-circuit transistor tester, Model 1890M.

Six major circuits are incorporated in the tester to accomplish the basic tests listed as follows:

a. I_{CBO} (collector leakage current)—A reverse voltage is applied across the collector-base diode of the transistor. The emitter is open circuited. (The transistor must be removed from its circuit for this test.)

b. I_C (collector current)—This test can be made with the transistors in the circuit. With the I_C potentiometer set to zero or its minimum position, note the shunt leakage current on the 0-1.0-mA scale. Under these circumstances, the meter is reading the stray leakage current flowing in the external circuitry because of the collector supply voltage.

c. Z ohms (external input impedance)—This test reverses the bias on the transistor so that it is cut off, separating the external input circuit from the transistor input resistance. You can read the value of the external input circuit impedance directly from the calibrated dials of the Z-ohms circuit potentiometers.

d. R_{In} (dynamic input impedance)—The dynamic input resistance of the transistor is determined by the same technique used in determining the external input circuit impedance. In the test, the transistor is biased in the forward direction, and the previous settings of the Z-ohms circuit potentiometers are retained. You find the value of the dynamic input resistance by varying the R_{In} transistor potentiometer until a null is indicated on the meter. You can read the value directly from the calibrated dials of the R_{In} transistor potentiometer.

e. Beta (current gain of a transistor in the common emitter configuration)—This test is concerned with the ratio of the AC collector current to the AC base current. To measure both of these currents, a monitoring resistor of 49.9 ohms is placed in a bridge circuit and another monitoring resistor of 1 ohm is placed in the collector circuit. The meter monitors the voltage drops across these resistors and the AC beta can be determined.

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Exercises (074):

1. What is the in-circuit-type transistor tester, Model 1890M, designed to do?

2. How many major circuits are contained in transistor tester, Model 1890M, for basic testing?

3. Reverse biasing the collector-base junction tests what characteristic of a transistor?

8-7. Power Meter HP-432A

075. Interpret given HP-432A power meter readings.

The Hewlett-Packard (HP) 432A power is the meter most widely used in our career field for making power measurements. The reason is that when it is properly calibrated it can be used to measure the power outputs of each type of radar transmitter we use. The HP-432A power meter uses a thermistor bridge network and requires the use of a thermistor mount to complete the circuit. The thermistor mount is connected between the meter and the RF input to the meter.

Temperature stability is critical for the proper operation of the HP-432A and it should be allowed to warm up for approximately 10 minutes before use. The thermistor mount is also a temperature sensitive device and care should be taken not to hold it in your hand.

Figure 8-29 shows the front panel of the HP-432A. The following is a brief description of the controls and their use:

a. Off/On—pushbutton switch that glows when it is on.

b. Range Switch—used to select the power measurement range. Range settings are used with the meter reading to get the actual power. The inside settings are shown in dBm.

c. Coarse Zero—with no RF applied and the range switch set to course zero, adjust for the proper indication.

d. Fine Zero Switch—toggle switch to electronically fine zero the thermistor compensation bridge. It should be used with no RF applied and with the range switch on the range to be used.

e. Mechanical Meter Zero—with no power applied, adjust it clockwise until the needle drops below, then balances at zero. Adjust slightly counterclockwise after zeroing to free the needle from the adjusting mechanism.

f. Meter—to get the power reading, subtract the meter reading (dBm) from the value of the range switch position.

g. Calibration Factor—set the switch to the reading marked on the thermistor mount. The purpose is to match the characteristics of the mount to meter. It may be necessary to reset the calibration factor for each different transmitted frequency (because of SWR) you check, or you may have to leave the switch in one position and use a conversion chart provided by your PMEL.

h. Mount Resistance Switch—to be left in one position to match your thermistor mount. The 478A (most common) uses the 200-ohm position.

Exercises (075):

1. The 432A has a meter reading of -6 with the range switch set to zero and external attenuation equal to 45 db. What is the amount of dBm being measured?

2. The power reading on the 432A keeps creeping higher while you watch it. What could be the problem?

3. Your power meter is broken so you borrow a 432A from NAVAIDS. What must you check before using this meter?

8-8. Spectrum Analyzer

076. Identify the purpose and basic functions of a spectrum analyzer.

Spectrum Analyzer. The spectrum analyzer, like the oscilloscope, is an extremely useful piece of test equipment. The analyzer can tell you a great deal about the EF signals it receives. While there are several different makes of spectrum analyzers in use, and though some have unique features, they all function in essentially the same manner and serve the same basic purpose.

The spectrum analyzer's main purpose is to evaluate the condition of a radar system's magnatron (or magnatrons) and related waveguide plumbing. Basically, the principles for a spectrum analyzer's sweep and display circuits are the same as an oscilloscope. The following discussion will cover primarily those controls that are not common to an oscilloscope but are found in most spectrum analyzers.

Baseline clipper. The base portion of a displayed spectrum is the most crowded and the intensity of the section may bloom as you try to optimize the upper portions of the display. Using the baseline clipper you may blank the display from the bottom, upwards. This blanking has no effect on signal amplitude; it merely allows you to blank portions of the display that are not needed for measurement.

Sweeptime controls. The sweeptime controls allow the unit to be used essentially as an oscilloscope. Normally, with a frequency spectrum displayed, it is measured in frequency per division and the use of the sweeptime controls is limited.

X, Y, and pen lift. These outputs are used to drive a plotter or similar writing unit for providing a permanent record of the displayed spectrum.

X and Y gain. Control of the X and Y (horizontal and vertical) gain calibration is normally limited to PEML, but some of the newest analyzers are equipped with external operator adjustments for use with the internal test set calibration signals. Caution must be exercised when making these adjustments to insure compliance with proper proce-

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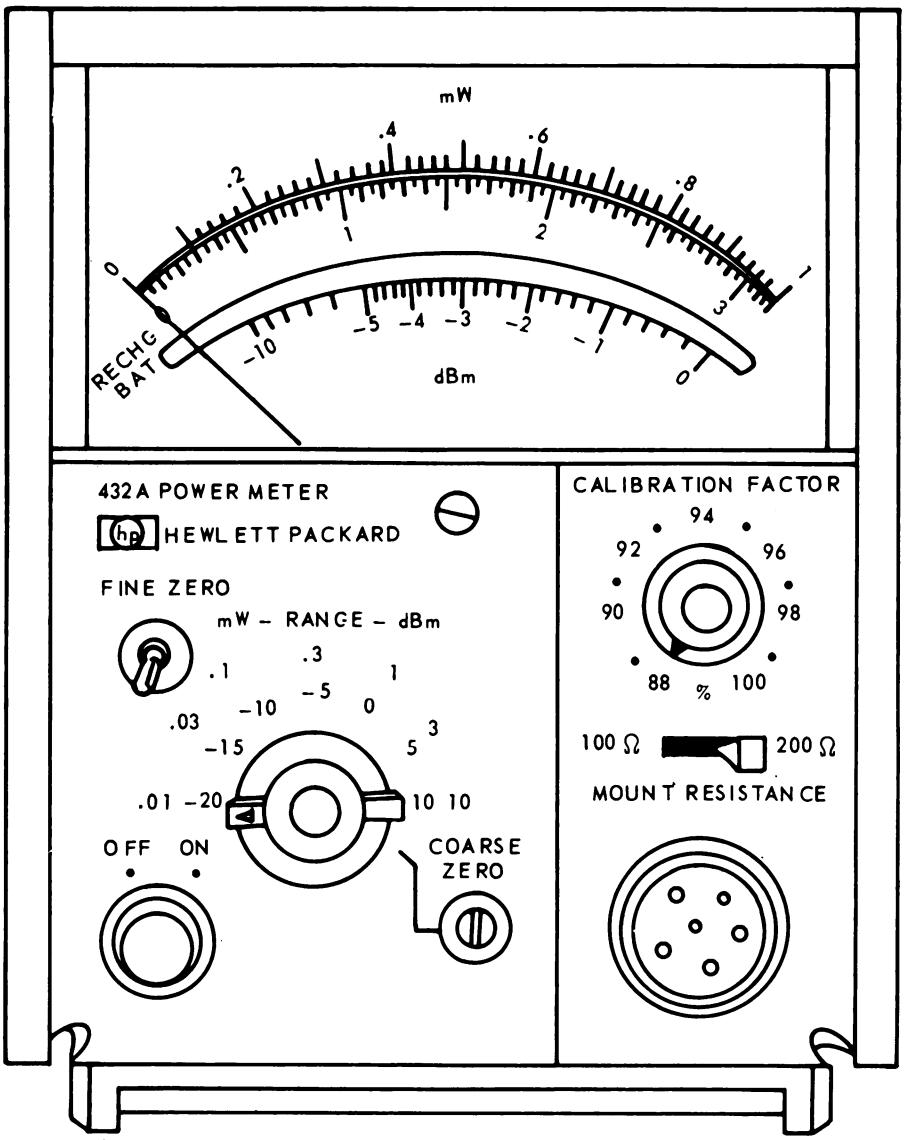

Figure 8-29. HP-432A power meter.

dures since these adjustments will effect frequency and amplitude calibrations.

Persistence. The persistence control allows the display endurance to be varied. An oscilloscope display will usually fade as fast as it sweeps to protect the CRT. This control can be adjusted so that the display will remain on the CRT for longer periods. This is done by allowing each new trace to build on what was displayed before. By using this control, a spectrum can be displayed as a solid block, but you must exercise care not to burn the CRT by overusing this control. The persistence control is not available when the display unit is used as an oscilloscope.

Write. The write button is used to start the operation in the variable persistence mode. Again, remember this function is not available when the display unit is used as an oscilloscope.

Store. When a spectrum taken "now" is needed to be viewed "later," use the store function. This function will serve as a memory and keep the display on the CRT at a reduced intensity for up to several hours, or even days, with or without power applied. If necessary, you may store more than one spectrum by storing one and then moving the trace (so as not to superimpose) and then storing the next, etc.

Erase. Since variable persistence and store functions allow displays to be kept on the CRT for extended periods, an erase function is provided to clear the CRT.

Conventional. The conventional (CONV) switch will switch the analyzer between operation as an analyzer or an oscilloscope. In this mode of operation, the time function is dominant over frequency functions.

Analyzer Section. The analyzer portion of the spectrum analyzer contains the RF and IF sections that control the frequency tuning, reference levels, bandwidths, etc.

CAUTION: The RF section uses an input crystal mixer diode that can be easily overloaded and destroyed if too high an RF input is inserted. To help prevent this, always set the input attenuation controls to maximum before attaching an

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RF input, especially if the RF input amplitude is unknown or even suspected of being high.

Log-Lin. Since a spectrum analyzer is measuring the frequency and power of RF signals, the vertical reference graticule will be scaled in dBm as well as linear units. The Log-Lin switch will enable switching between the logarithmic function, read in dBm, and the linear function. In linear, the signal amplitude can be compared for both voltage and fractional dBm differences.

Reference levels. When viewing the spectrum you can adjust the reference levels to provide the optimum visual display. The level controls are marked in dBm so as to permit accurate dBm measurements even after attenuating or amplifying the signal. These controls may have external calibration adjustments to insure correct amplitude display.

Signal identification. The signal identification (Sig Ident) function provides a reduced amplitude image of the center frequency (CF) signal. With the correct frequency range selected, the image will appear at a predetermined spot, normally to the left of the CF signal.

Scan/span. The frequency scan/span selections will be calibrated in frequency-per-division increments. The scan/span modes that are usually selectable include the following: full scan mode, which displays the entire frequency range selected; start mode, which displays the main frequencies of interest at the left of the CRT; CF or normal modes, where the main signal is displayed in the center of the CRT; time domain or zero frequency modes, where the horizontal display is time oriented and not frequency calibrated.

External mixer. The external mixer (Ext Mixer) is one of several possible front panel conductors that should be terminated with a 50-ohm load, unless in use.

Exercises (076):

1. What is the basic difference between the spectrum analyzer as an analyzer and as an oscilloscope?

2. If the peak of the displayed spectrum is too dim to see well, and the button looks so bright that you fear you might burn the CRT, what can you do?

3. Why should you be careful when using a high persistence?

4. How can two spectra be compared on one analyzer?

5. If you want to check the spectrum of a signal but you don't know its power level, what should you do?

6. In the normal scan mode, where would the signal of interest be?

8-9. Radar Test Set AN/UPM-137

The radar test set, AN/UPM-137, is a valuable aid in the maintenance of the TPX-42 SIF equipment. A basic understanding of its functional operation and capabilities will assist you in performing the checks and alignments required to keep the interrogator equipment on the air. Since you are only required to operate the test set, our discussion includes only the front panel controls and the input/output signals that are used to perform your tests.

077. Give the purpose of the AN/UPM-137 and identify the four modules it contains.

The AN/UPM-137 test set is actually four test sets combined into one case. Use of this unit is required to properly maintain the IFF interrogator and transponder equipment. The AN/UPM-137 is a specialized piece of test equipment with the versatility of providing any signal or combination of signals that will allow you to accurately check the performance of a large part of the TPX-42, including the following components:

- Receiver/transmitter unit.
- Interference blanker.
- Antenna switch control.
- Signal processor.
- Video signal processor.
- Range azimuth beacon monitor (RABM) TPX-49.

The AN/UPM-137 consists of four separate modules powered by a common internal power supply. The modules may be used independently or in conjunction with each other and are arranged as shown in figure 8-30.

The oscilloscope (OS-208/UPM-137) is located in the top left corner of the case, and it provides all of the features required for measuring the pulse and signal characteristics of the test set and the IFF equipment. Immediately to the right of the oscilloscope is the interrogator signal simulator (SM-559/UPM-137). This unit provides RF signals for radar video simulation and active readout signals for testing radar display systems. The selective identification signal (SIS) generator (SG-865/UPM-137) is located in the lower left corner. The SIS generator is used to produce test SIF pulse trains, triggers, and pulses for testing and aligning the SIF interrogator, transponder, and display system equipment. Just to the right of the SIS generator is the radio-frequency (RF) signal generator (SG-866/UPM-137). This module generates, mixes, and demodulates the RF signals required to check the interrogator transmitter and receiver. Located between the oscilloscope and interrogator signal simulator modules is an accessory box that is used for storing all accessories used with the test set.

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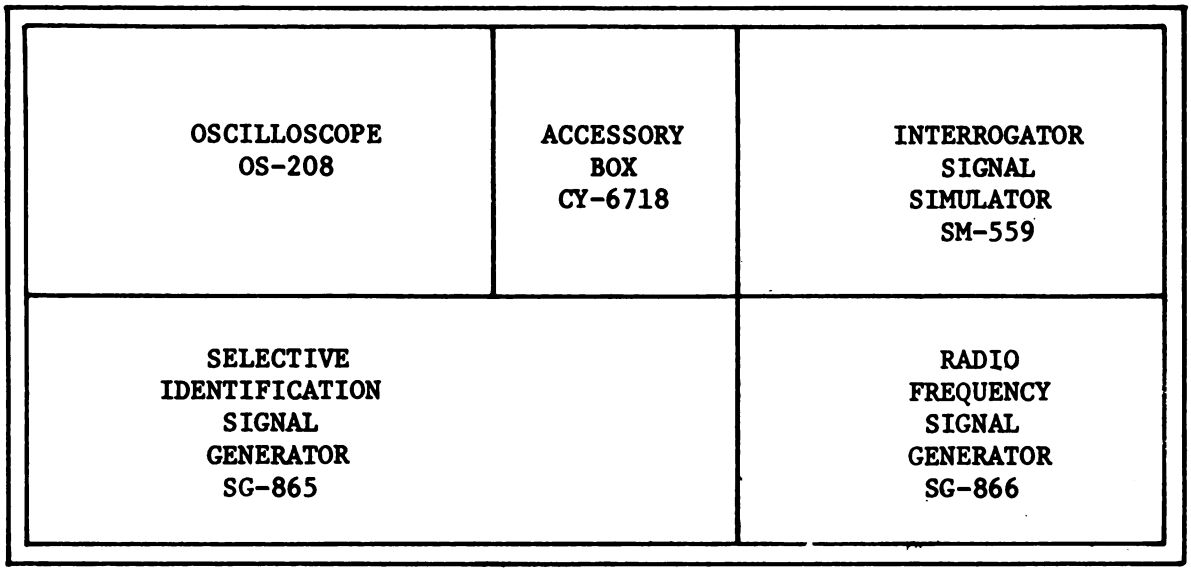

Figure 8-30. Radar test set AN/UPM-137 module location.

Exercises (077):

1. What is the functional purpose of the AN/UPM-137?

2. Beginning with the module in the top left corner of the case, and moving in a clockwise position, list the modules as they are mounted in the AN/UPM-137.

078. Describe the output signals available from the SIS generator module.

Figure 8-31 shows the front panel layout of the controls and switches of the SIS generator. As you can see, there are a large number of them, and they are all necessary to provide the following IFF test video.

a. Two independent SIF pulse trains.
b. Challenge/tag video (modes 1, 2, 3/A, 4, and C) and side-lobe suppression (SLS) challenge/tag video.
c. Reset video.
d. Word A or B (mode 4), with or without SLS pulses.
e. Suppressor pulse.
f. Triggers (delayed and undelayed).

The video outputs from this unit can be used to modulate the RF from the RF signal generator for receiver checks or as raw video for checking the display systems.

The SIF 1 pulse train is produced and controlled at the SIF 1 CODER when the MIXED VID SEL switch is set at any SIF position. The FUNCTION SEL switch will establish any one of five pulse train formats.

(1) NORMAL—includes F1 and F2 bracket pulses and 12 selectable information pulses.
(2) NORMAL + X (N+X)—includes a fixed pulse in the X pulse position of the pulse train.
(3) EMERGENCY—includes normal pulse train followed by three sets of bracket pulses.
(4) VARIABLE EMERGENCY—same as preceding train except spacing between the pulse train and each set of bracket pulses can be simultaneously varied.
(5) IDENTIFICATION/POSITION (I/P)—includes a normal train followed by a special position identifier (SPI) pulse.

All pulses except the F pulse in the train can be substituted with a variable substitution pulse. The pulse widths are simultaneously adjusted with the WIDTH ADJ control. This control should be kept as far CCW as the test procedures allow to prevent severe distortion of the pulse train. The SIF 1 pulse trains are available at the MIXED VIDEO VAR AMPL 0-5V OUT and HIGH-LEVEL 15V OUT jacks. It should be noted here that a SIF 2 train is available at the SIF 2 OUT jack during any SIF 1 train operation.

Both SIF 1 and SIF 2 pulse trains are available at the mixed video output jacks in the SIF 1, SIF 2, or ALL SIF positions of the MIXED VIDEO SEL switch. The SIF 2 trains are controlled by the SIF 2 CODER and do not contain the X pulse, emergency train, or I/P option. The delay between the SIF 1 and SIF 2 trains may be varied with the TRIG DELAY control until they are interleaved or completely separated. A 4.35-microsecond spacing between the two can be used to obtain a mode 2 emergency train.

The challenge tag and reset generators produce challenge/tag and reset signals with variable spacings. These signals can be used to check out the standby transmitter/receiver unit without using the triggers from the operational unit. Challenge/tag includes modes 1, 2, 3A, C, and 4 in interlaced and repeated modes, with or without side-lobe suppression (SLS). Each individual MODE switch placed in the

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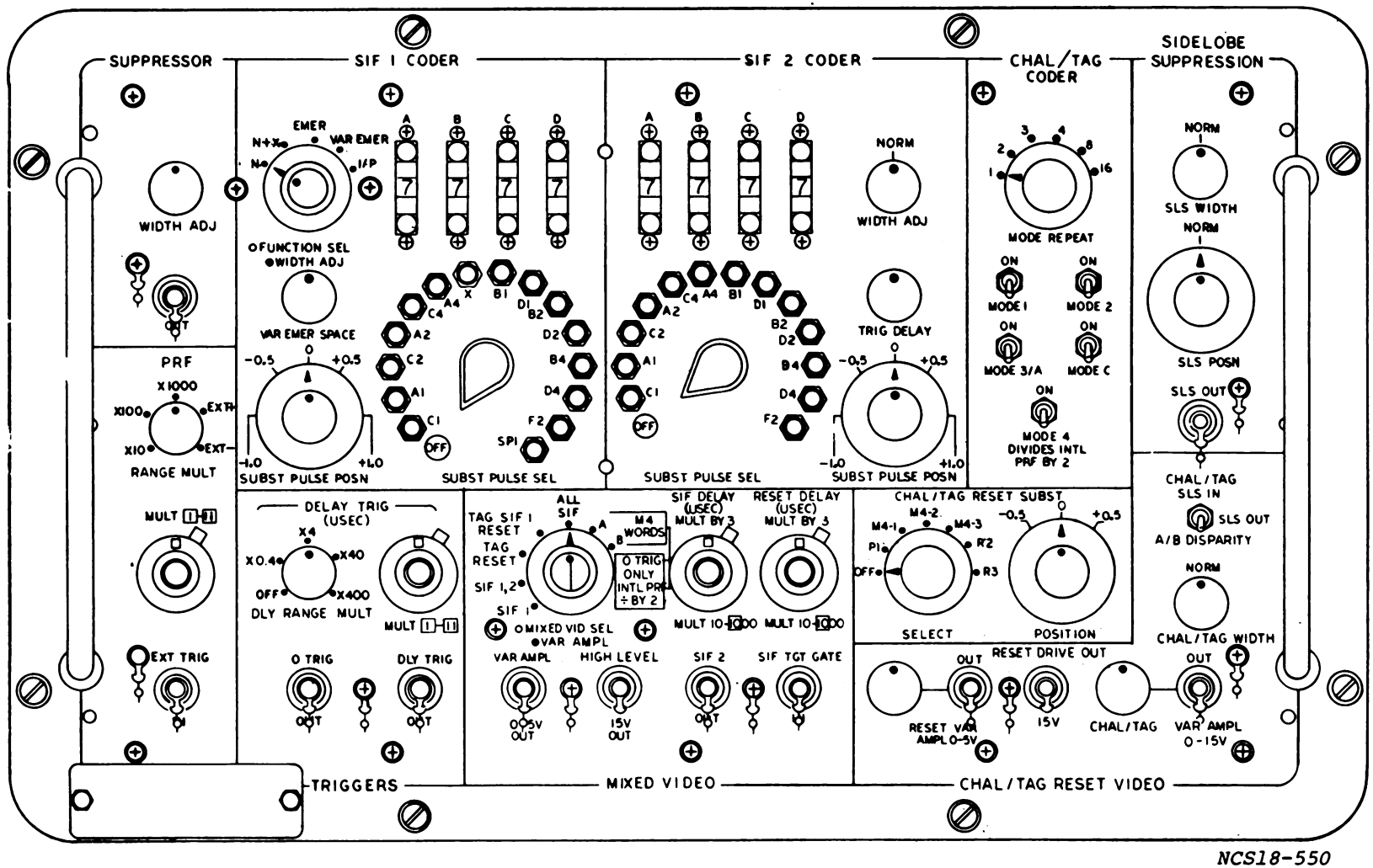

Figure 8-31. SIS generator module front panel layout.

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ON position will cause its P1 pulse to appear in the signal. The selected modes can be repeated 1, 2, 3, 4, 8, or 16 times, depending on the setting of the MODE REPEAT switch. The modes are produced in numerical sequence (111222333 for count 3) and are skipped if not selected. The chalge/tag output is continuous, repeating the numerical sequence selected. The P1 pulse may be substituted with the CHAL/TAG RESET SUBST SELECT switch and POSITION control. A challenge/tag SLS pulse can be introduced with the CHAL/TAG SLS A/B DISPARITY switch by placing it in the SLS IN position. The position and width of the SLS pulse can be adjusted by the controls in the side-lobe suppression section of the panel. Challenge/tag and SLS video are available at their individual output jacks and at the mixed video outputs.

The SIS generator may be triggered internally or by using a positive or negative external trigger source. Two triggers are available for synchronizing other equipment with the test set. The primary trigger is the "0" trigger, and the other is the delayed trigger. The amount of delay is dependent on the position of the DLY RANGE MULT switch and MULT control. The DLY RANGE MULT switch should be initially set to the X400 position, as noted in the control normalizing procedure later in this section. If you do not have this control in the X400 position, you may not be able to obtain a video display.

The suppressor pulse is always available at the SUPPRESSOR OUT jack and is independent of all SIF CODER functions. Its duration is set with the WIDTH ADJ control. This pulse is used to test the receiver suppressor circuits of the IFF equipment.

Exercises (078):

1. List the five pulse train formats available from the SIF I coder.

2. With the MODE REPEAT switch in the 4-position and the MODE 1 and MODE 3/A switches in the ON position, what will be mode sequence out of the Chal/Tag Coder?

3. List three types of video available from the SIS generator.

079. Describe the output signals of the interrogator signal simulator.

The interrogator signal simulator (SM-559/UPM-137) module produces RF signals for transmitter/receiver test procedures and radar video simulation and active readout signals for testing radar display systems. This module consists of four sections: a system simulator, transmitter, 60-MHz sweep generator, and PRF counter section. Figure 8-32 shows the front panel layout of the interrogator signal simulator.

The PRF counter is used to indicate the PRF of the system under test. The LEVEL position of the Meter Select switch is used in conjunction with the RF signal generator module to calibrate the 60-MHz signal output.

A fixed 1090-MHz CW signal or a 1070-MHz sweep signal is generated in the transmitter section. These signals must be coupled through the RF signal generator module for RF level control and demodulation. Another output of this section is frequency markers. These markers are used with the 60-MHz sweep frequency signal and represent the center frequency and the ±3, ±5, ±10, and ±20-MHz points. The sweep sync out jack provides a signal that can be used to synchronize the oscilloscope with the sweep signal. Notice that the XMTR FREQ switch is labeled XTAL and SWEEP with a placard to the right denoting that the 60-MHz SWEEP position is the down position. This position of the switch is used for the 1070-1110 MHz and the 60-MHz sweep signals. To obtain the 60-MHz sweep signal, you must connect the 1030-MHz output of the RF signal generator to the EXT RF IN 1030 MHz jack in the 60-MHz sweep generator section.

The system simulator section produces three simulated radar video pulses having different widths and amplitude. These pulses can be provided with or without noise and are used to test the radar display video circuits. The video levels are simultaneously controlled with the video level control. The amplitude and noise levels are adjusted to establish various video input conditions for the display system circuits. The output for these signals is the radar simulator out jack.

Also available from the system simulator section are the active readout signals. These signals represent a target area approximately 15 miles within a 3° to 10° sector. Antenna azimuth rotation data (ACPs and ARPs) simulating an antenna rotation speed of 6 rpm are generated for the active readouts. The SIF TGT GATE OUT jack should be connected to the SIS generator to synchronize its SIF pulse train within the target area.

Exercises (079):

1. Describe the signals available from the transmitter section of the interrogator signal simulator.

2. What type of signals are produced in the radar simulator section of the system simulator?

3. Describe the output of the 60-MHz sweep generator section of the interrogator signal simulator.

080. State the purpose of the RF signal generator module, and list the signals available from its transmitter section.

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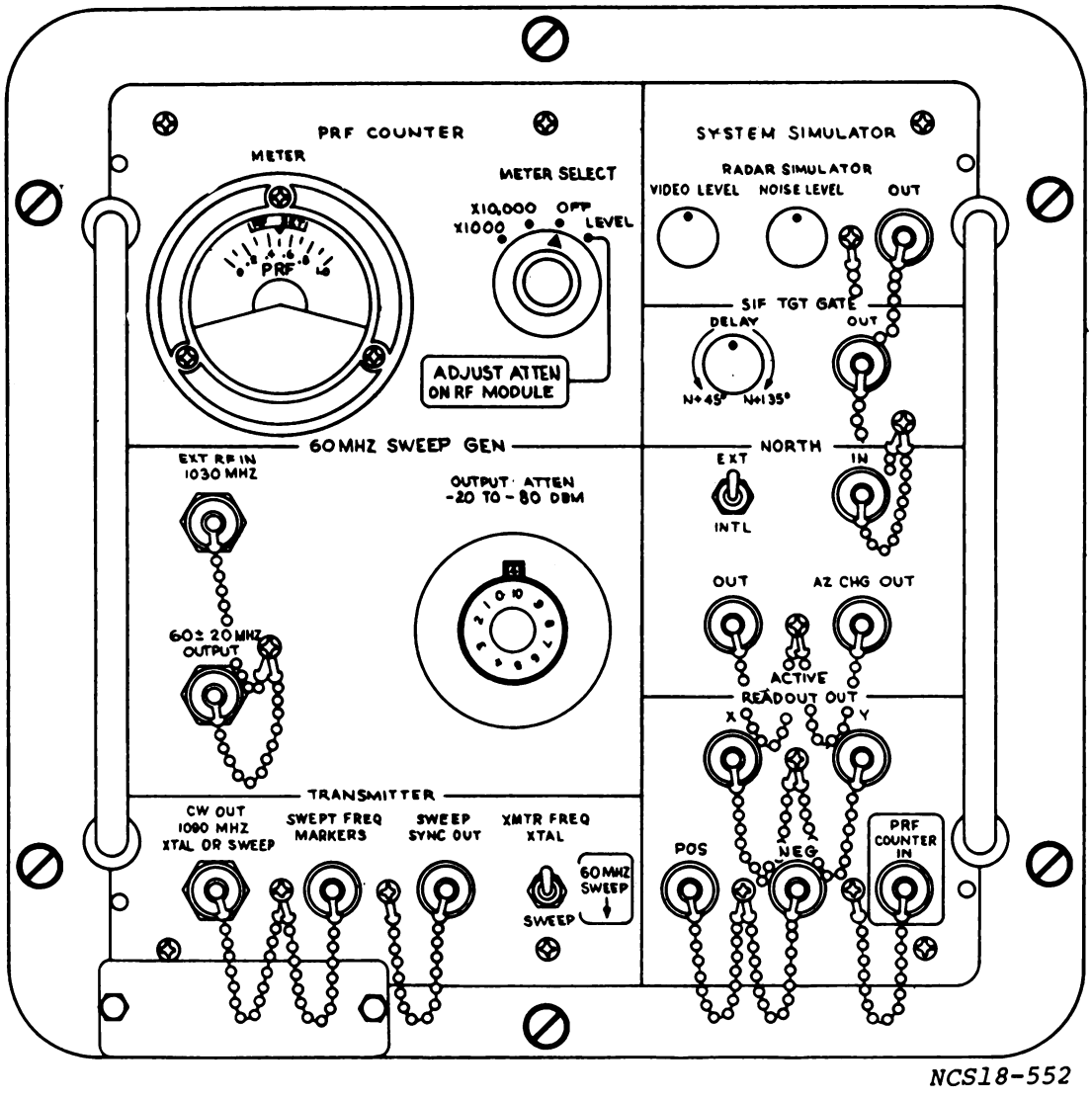

Figure 8-32. Interrogator signal simulator front panel layout.

The RF signal generator (SG-866/UPM-137) generates, mixes, demodulates, and controls the RF level of the signals required to test and align the interrogator transmitter and receiver. The attenuation controls are used to control the RF level of the signals produced by the module and the level of the RF applied from other sources. As you can see in figure 8-33, this module is divided into three sections: video, transmitter, and RF.

All of the signals demodulated by the RF signal generator are available at the VIDEO OUT jack of the video section. Two modulation inputs, auxiliary and main, are provided to produce RF pulses at two separate levels. The AUX ATTEN control is used to control the RF level of the auxiliary RF path, and the OUTPUT ATTEN control sets the level of the RF in the main RF path. By connecting the MOD OVERRIDE (CW) jack to either modulation input, a CW RF signal is produced at the SIG GEN RF IN/OUT jack.

The transmitter section provides a 1030-MHz crystal-controlled frequency or a 1010-1050-MHz sweep frequency, depending on the position of the XMTR FREQ switch. These signals are available at the RF SIG GEN IN/OUT jack. The CW SOURCE switch is used to enable the external 1090-MHz signal from the interrogator signal simulator to be routed through the RF signal generator for RF level control. The swept-frequency marker and sweep-sync output signals are identical to the signals described in the interrogator signal simulator. The output of the FREQ PROBE jack is the result of heterodyning the RF input under test with one of the radar test set RF sweep signals. This output will provide you with a video signal during transmitter frequency checks.

In the RF section, the POWER PROBE RF IN/OUT jack is used for connecting the interrogator transmitter output directly to this module. Depending on the power level input, the HIGH or LOW POWER PROBE jack is then connected to the SIG GEN IN/OUT jack. If the power-level inputs are 50W or less, it can be connected directly to the SIG GEN IN/OUT jack. The RSLS (receiver side-lobe

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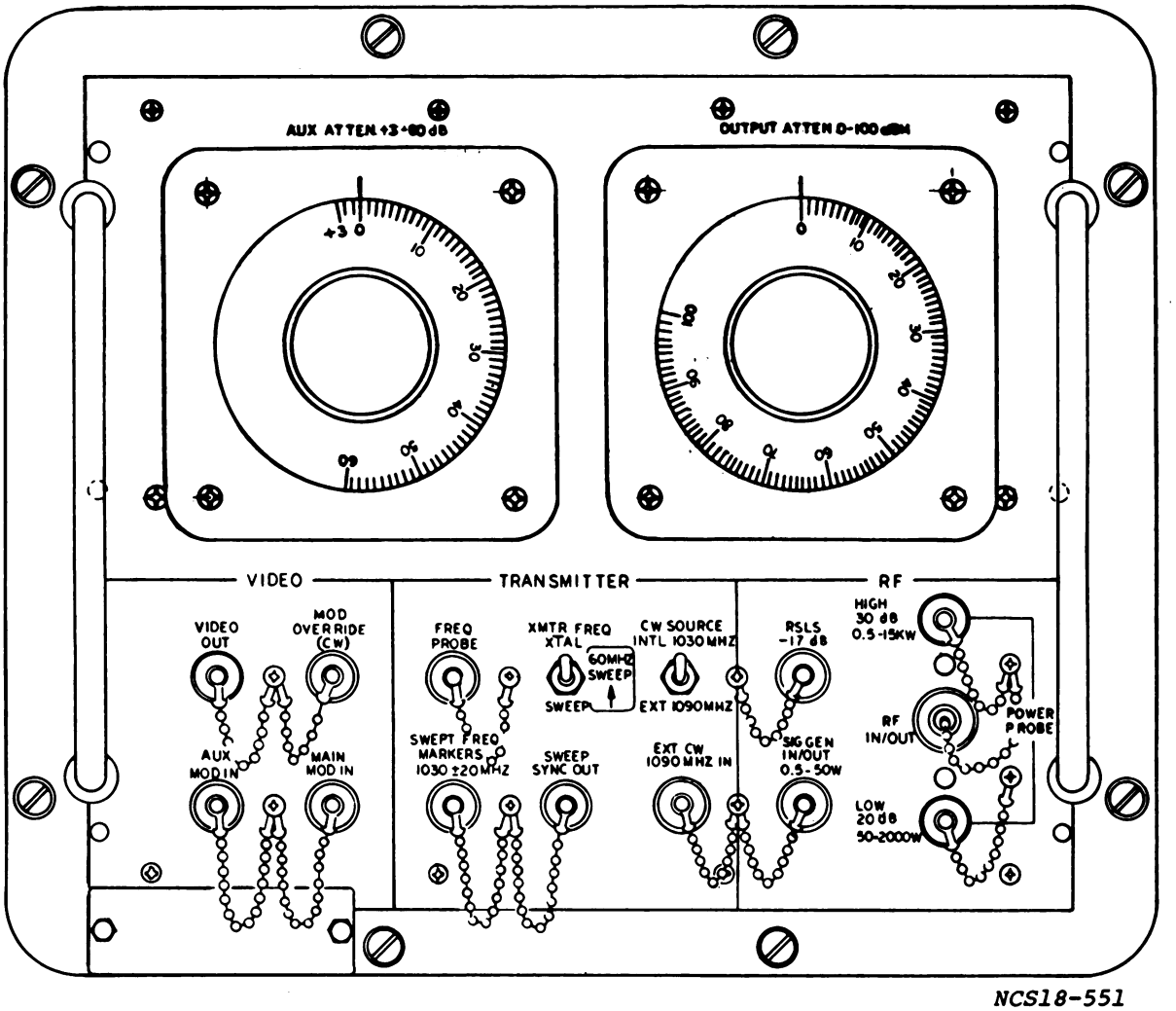

Figure 8-33. RF signal generator front panel layout.

suppression)—17 dB jack provides RF that is attenuated with respect to the auxiliary RF path. This output is used as the difference antenna input for SLS checks.

Exercises (080):

1. List the five signals available from the transmitter section of the RF signal generator module.

2. What is the purpose of the RF signal generator module?

081. Describe the methods used to add frequency markers to the A and B sweeps of the oscilloscope module.

With the build-in oscilloscope (OS-208/UPM-137), it is not necessary for you to set up an additional piece of test equipment to accomplish your checks and alignments of the TPX-42 equipment. This module provides all of the features required for measuring the pulse and signal characteristics of the test set and interrogator equipment. Figure 8-34 shows the front panel layout of the oscilloscope, and, as you can see, it contains the same controls found on most dual-trace scopes. An added feature of this unit, however, is the internally generated frequency markers that can be added to the B channel sweep. The XTAL MARK (USEC) switch in the lower right corner allows you to add the desired frequency markers to the B channel sweep. Also, frequency markers from either the interrogator signal simulator or the RF signal generator may be added to the A channel sweep. These markers are applied to the FREQ MARK IN jack located in the center of the vertical section of the scope.

Exercises (081):

1. How are frequency markers added to the B channel sweep?

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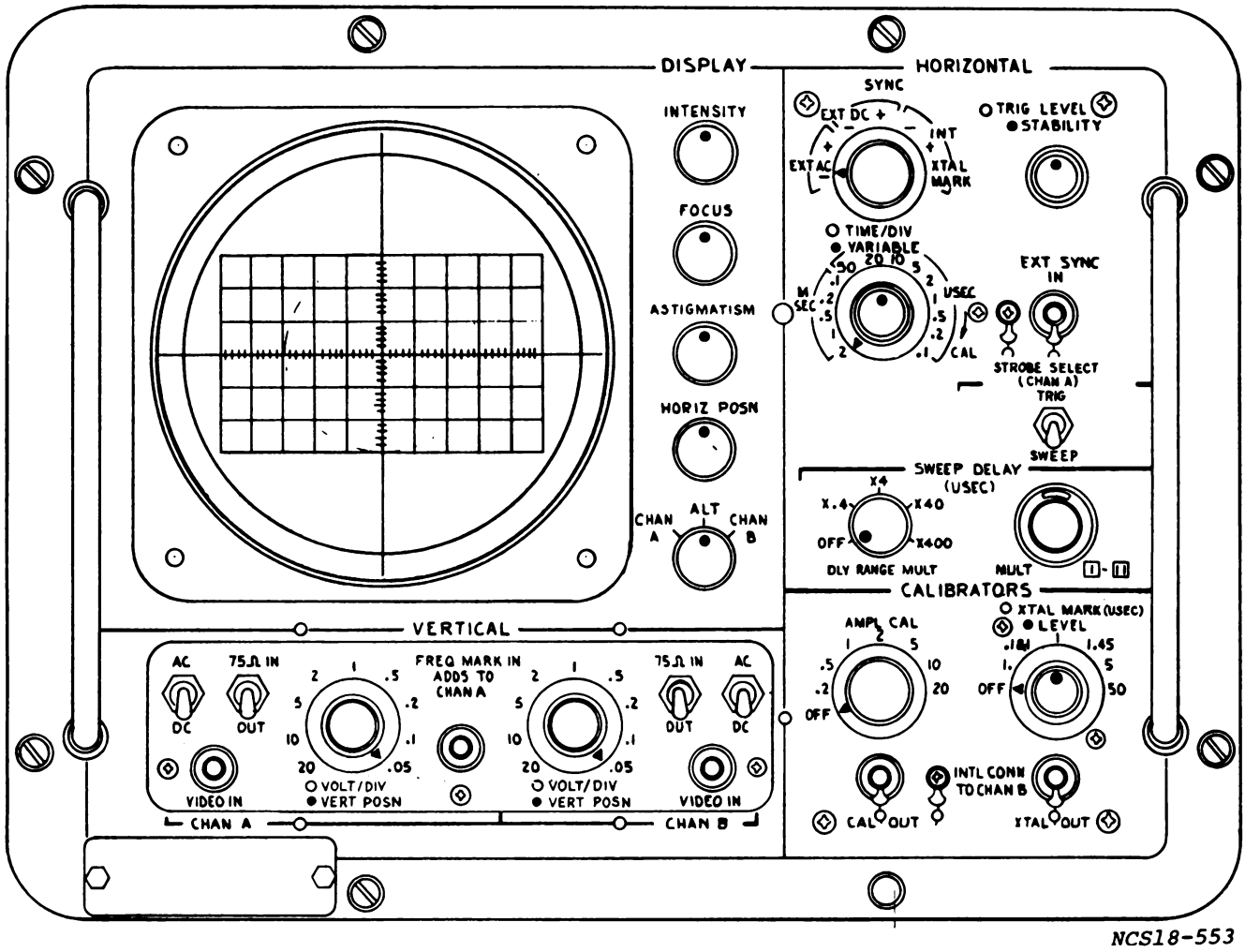

Figure 8-34. Oscilloscope module front panel layout.

2. Where are the frequency markers from the RF signal generator applied to add them to the A channel sweep?

082. State the purpose of the operating procedures for the AN/UPM-137 and cite testing precautions.

Due to the many signals required to perform some of the maintenance checks with the AN/UPM-137, you may find yourself tangled up in RF video cables if you are not careful. Here are a few rules you should follow to prevent that from happening and to simplify your operation of the test set.

(1) Never connect a short cable to the AN/UPM-137; otherwise, the test set may be changed.

(2) Doublecheck your connections to be sure you are not connecting to the wrong jack.

(3) Use test cables of sufficient length to make your connections; too long is just as bad as too short.

(4) Keep the cables, connectors, and probes off the floor. In addition to getting stepped on, they could also cause someone to trip and fall.

(5) Store the test cables and probes in the accessory case provided.

(6) Treat the test cables with the same care that is required for the test set; after all, they are part of the test equipment.

As you have probably already discovered, it can be very frustrating to complete a test procedure hookup and not be able to complete the procedure because of defective test cables or malfunctioning test equipment. By following the rules above and by taking proper care of the test equipment you will not make your job more complicated than it is.

Prior to using the AN/UPM-137, it is necessary to set the controls and switches to certain specified positions. If this is not accomplished, you may have difficulty in achieving the proper results from the test procedure. Table 8-1 gives the required control positions for what we call "normalizing" the controls of the AN/UPM-137."

As with any new system or piece of test equipment, proficiency is attained only through practice. By applying a reasonable amount of attention to detail and analyzing the purpose behind each step of the procedures, your proficiency with the AN/UPM-137 should increase each time you use it. This test set is a vital part of the TPX-42 maintenance requirements. By following the procedures as they are

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listed in the technical orders (TOs), you should not have any difficulty in becoming proficient with this test set.

Exercises (082):

1. List three precautions that should be taken when the AN/UPM-137 is being connected for a test procedure.

2. Why should you follow the procedure of normalizing the controls of the AN/UPM-137?

TABLE 8-1
CONTROL POSITIONS FOR NORMALIZING THE UPM-137

SIS GENERATOR	
WIDTH ADJUST	fully CCW
PRF	EXT +
MULT 1-11	fully CCW
FUNCTION SEL	N
WIDTH ADJ	fully CCW
VAR EMER SPACE	Midrange
SUBST PULSE POSN	0
SUBST PULSE SEL	Off
SIF 2 WIDTH ADJ	NORM
SIF 2 TRIG DELAY	fully CW
DELAY RANGE MULT	X400
(DELAY TRIG) MULT 1-11	fully CCW
MIXED VIDEO SEL	SIF 1
VAR AMPL	fully CW
SIF DELAY MULT BY 3 10-1000	fully CCW
RESET DELAY MULT 10-1000	fully CW
MODE REPEAT	1
MODE 1	Off
MODE 2	Off
MODE 3	Off
MODE C	Off
MODE 4	Off
CHAL/TAG SELECT	Off
CHAL/TAG POSITION	0
RESET VAR AMPL 0-5	fully CCW
SLS WIDTH	NORM
SLS POSN	NORM
SLS IN/OUT	OUT
CHAL/TAG WIDTH	NORM
CHAL/TAG VAR AMPL	fully CCW
INTERROGATOR SIGNAL SIMULATOR	
METER SELECT	OFF
XMTR FREQ	XTAL
RF SIGNAL GENERATOR	
AUX ATTEN	0
OUTPUT ATTEN	0
XMTR FREQ	XTAL
CW SOURCE	INTL 1030 MHz

NCS18-56C

8-10. Organizational and Intermediate Level Maintenance on Category I and Category II Test Equipment

Economy, mission, and combat effectiveness demand that maximum maintenance be performed at the lowest practical organizational element. Because of the location of most ATC sites, both organizational and intermediate level maintenance are performed there. This scope of responsibility also includes test equipment. Firm maintenance discipline is necessary, and all supervisors must maintain self-sufficiency at this level. Let's look at your responsibilities for organizational and intermediate level maintenance of Category I and Caregory II test equipment.

083. Identify the level of maintenance required for specific categories of test equipment.

For maintenance purposes, test equipment is divided into four categories. All test equipment in your area of maintenance responsibility falls in either Category I or Category II:

a. Category I—This category includes all operational test equipment installed in a system as an integral part of the system. Examples of this category are the ammeters, voltmeters, and oscilloscopes that are built into the system.

b. Category II—This category includes all equipment that is used to check Category I test equipment. This group may include such devices as the PSM-6 multimeter, counters, and frequency meters.

Don't misunderstand. You are not responsible for all Category I and Category II test equipment, but all the equipment that you are responsible for falls into one of these two categories. Full explanations of responsibilities toward RMEL is contained in TO 33K-1-100.

There are two organizations that have the primary responsibility for maintaining equipment in Categories I and II. These are (1) the using organization of which you are a part, and (2) the base's precision measurement equipment laboratory (PMEL). As part of the using organization, you have the responsibility for the calibration of your Category I and Category II equipment, with the following exceptions:

a. Base PMEL calibrates all the general-purpose and commercial Category II test equipment that can be removed to the PMEL. This does not include the test equipment that must be calibrated while it is in data processing equipment.

b. Maintenance of test equipment that requires special skills or special equipment (whether it be Category I or II) that is available only at the PMEL is the responsibility of the base PMEL.

Organizational Maintenance. Organizational maintenance on precision measurement equipment normally consists of preventive maintenance operations performed by the equipment's user, operator, or operating crew. This preventive maintenance is limited to the proper use, cleaning, preservation, servicing, minor repairs, and accomplishment of work specifically designated as organizational maintenance by technical directives. Excluded is any work that requires the

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adjustment or replacement of parts or components that affect the calibration of the equipment.

Intermediate Maintenance. Intermediate maintenance includes the maintenance of precision measurement equipment that is beyond the responsibility of the organizational maintenance activity. This includes repairs requiring fixed laboratory and ground mobile equipment, the replacement of major unit assembles and components, and the fabrication of parts. Category III precision measurement equipment is used for maintenance, troubleshooting, testing, verification, and calibration of non-PMEL equipment as well as Category I and Category II test equipment; it is maintained by the precision measurement equipment laboratory (PMEL), using Category IV test equipment.

Scheduling. The PMEL should automatically reschedule your test equipment and call for it when its calibration is required. If you determine that calibration is required sooner than the scheduled date, you must contact PMEL and have it reschedule that particular test set. When possible, you must report your regular calibration requirements to the PMEL to insure prompt compliance.

Exercises (083):

1. Base PMEL calibrates all general-purpose and commercial Category _____ test equipment that can be removed to the PMEL.
2. Precentive maintenance, short of adjustment or parts replacement on test equipment, is normally performed at the _____ level of maintenance.
   nance.
3. The test equipment that is built into a system belongs to category _____.

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AFR 205-57. *Reporting and Countering the Hostile Human Resources Intelligence Threat.*

AFR 207-1. *The Air Force Physical Security Program.*

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Answers for Exercises

CHAPTER 1

Reference:

001 - 1. The mandatory requirements are items a, b, d, f, g.

002 - 1. At the 7 skill level.
002 - 2. At the 5 skill level.
002 - 3. At the 7 skill level.

003 - 1. As part of the JQS.
003 - 2. How to analyze the results of the performance checks.

004 - 1. Field evaluation visits and direct correspondence questionnaires.
004 - 2. The Specialty Training Standard.
004 - 3. AF Form 1284.

CHAPTER 2

005 - 1. If not corrected quickly, the substandard condition could become accepted as the standard.
005 - 2. During the daily activities.
005 - 3. By analyzing the maintenance reports.
005 - 4. Care must be taken to insure that the charts and graphs are readable and understandable.
005 - 5. To show newly arrived personnel how they fit into squadron mission.
005 - 6. The functional chart.

006 - 1. TAs are based on the mission assigned to an Air Force activity.
006 - 2. The major commands and Allowance and Authorization (A&A).
006 - 3. Bench stock is a source of expendable items that permits work to be accomplished without interruption due to lack of supplies.
006 - 4. Items which are either consumed, or base their original identity by incorporation into another assembly.
006 - 5. Allowance and Authorization (A&A).

007 - 1. (1) Cash Collection Voucher, DD Form 1131, and (2) Statement of Charges, DD Form 362.
007 - 2. The top price is the full price while the bottom price is the price the Air Force is to collect from the individual. This reduction is allowed but may not exceed 25 percent.
007 - 3. His or her signature on the statement of charge form indicates: (1) acknowledgement, (2) authorization, (3) waiver of right, (4) an affirmation, and (5) an agreement.

008 - 1. It explains and records circumstances involving lost, damaged, or destructed Air Force property.
008 - 2. The individual that has custodial responsibility at the time of loss.
008 - 3. No later than 30 days.

009 - 1. (1) Modification of equipment, (2) excessive overtime, (3) additional duties, (4) additional operating hours.
009 - 2. To insure that he or she has all the facts straight before going to higher commands for assistance.

CHAPTER 3

010 - 1. To follow and comply with sound security practices, to be familiar with the regulations and instructions, to protect all classified information you possess, and to make sure you do not cause others to violate security policies.
010 - 2. Check for access by competent authority, need-to-know information to perform duties, and can properly protect the information.

011 - 1. True.
011 - 2. True.
011 - 3. Change "unclassified" to "classified."
011 - 4. True.
011 - 5. Change "Secret" to "For Official Use Only."
011 - 6. True.

012 - 1. Information the disclosure of which could reasonably be expected to cause exceptionally grave damage to national defense.
012 - 2. Information the disclosure of which could reasonably be expected to cause damage to national defense.
012-3. Information the disclosure of which could reasonably be expected to cause damage to national defense.

013 - 1. It is prepared and issued by the commander or official charged with the responsibility for the plan, project, program, or operation.
013 - 2. True.
013 - 3. True.
013 - 4. It is prepared only by personnel who have at hand the necessary knowledge and technical intelligence to make reasonable determinations.
013 - 5. True.

014 - 1. The degree of classification, instructions for downgrading and declassification, office of origin, and date of origin.
014 - 2. On the top and bottom of the front cover, title page, first page, back page, and back cover.
014 - 3. Top and bottom of the page with the highest classification found on that page.
014 - 4. Each paragraph is marked with its own classification if it differs from the overall page classification.

015 - 1. The ability or opportunity to obtain knowledge of classified information.
015 - 2. It must be in use by or under the direct observation of an authorized person, or stored in approved locked containers, such as file cabinets, safes, alarmed areas, vaults, secure rooms, and secure areas.
015 - 3. Written permission of the person or office who originally made the document or higher authority in the same chain of command.
015 - 4. By burning, melting/chemical decomposition, pulping, pulverizing, mutilating, and shredding.
015 - 5. Record and certify the destruction on one of the forms listed in DOD 5200.1-R and AFR 205-1.
015 - 6. Report it to your supervisor or commander and they will take steps to protect plans, operations, or projects affected, and make the modifications necessary and initiate an inquiry to determine if a compromise did occur and conduct an investigation to discover the cause.

016 - 1. By escort or courier or by protected electrical means.
016 - 2. By registered U.S. mail or by the methods used for Top Secret.
016 - 3. Transmitted by certified or first-class mail or by means for Secret and/or Top Secret.

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017 - 1. To regulate the protection of classified Government information in the hands of industry.
017 - 2. The contractor must adhere to the same security practices followed for portecting, marking, and controlling the same category of information still in USAF possession.
017 - 3. It helps protect classified Government information by prescribing uniform security practices to be used in industrial plants, educational institutions, and other facilities used by contractors with access to or possession of classified information.

018 - 1. No. Sgt Jones should have spoken to someone who knew what Blue Knight was or used secure communications to discuss the project.
018 - 2. Yes.
018 - 3. Yes.
018 - 4. Yes.

019 - 1. Transmission security, cryptosecurity, physical security, and emission security.
019 - 2. Transmission security insures that the enemy does not intercept or exploit our communications. Physical security prevents an unauthorized persons from gaining access to COMSEC equipment, material, and documents. Cryptosecurity prevents an enemy from deciphering the meaning of transmitted information. Emission security denies unauthorized persons information that could be derived from intercept and analysis of compromising emanations from cryptoequipment and telecommunications systems.
019 - 3. Transmission security.
019 - 4. It affects every Air Force member. Everyone in the Air Force is likely to use the telephone to conduct USAF business.
019 - 5. Develop lists of EEFIs.

020 - 1. Telephone off the hook, unplanned conversations, attempting to disguise information, homemade codes, and ciphers.
020 - 2. Unplanned conversations.
020 - 3. Disguising the information or using homemade codes or ciphers.

021 - 1. When an enemy knows in advance they are going to be attacked, they have time to plan their counteractions or avoid that attack.
021 - 2. To keep the tactical and strategic advantage on our side by protecting information and activity regarding our plans.

022 - 1. Identify those portions of an operation that require protection, develop OPSEC procedures and techniques, systematically assess OPSEC status at all operational levels, and document deficiencies and institute corrective actions.
022 - 2. Operations, communications, and procedures.
022 - 3. Any type of information that could reflect a change in procedure or operations, whether the information seems important or unimportant.

023 - 1. Yes. This is a routine community relations effort, usually screened and cleared by the Public Affairs Office.
023 - 2. No. This conversation deals with a probable limitation on a strategic weapon system component.
023 - 3. No. This conversation deals with the distances to the location of strategic weapons systems components from a known point.
023 - 4. Yes. This is a routine story for acknowledging excellence.
023 - 5. No. This also appears to be a probable compromise of classified material, since the "(S)" indicates Secret classification.
023 - 6. No. This information reveals a probable change in some part of the missile system, thus pointing toward other changes.

CHAPTER 4

024 - 1. Standard publications.
024 - 2. Air Force pamphlets.
024 - 3. A field publication.
024 - 4. Supplements are filed behind the basic publication.

025 - 1. AFR 5-4, *Numbering Publications.*
025 - 2. The double number designates a specific subject; for instance, to locate publications pertaining to military personnel matters, we would want a publication that began with the number 35.
025 - 3. 34-1-9 is an Air Force pamphlet. This is indicated by its having a third digit.

026 - 1. AFR 8-2.
026 - 2. The applicable TO index. 31 category for the AN/MSQ series.
026 - 3. 00-5 series technical orders give a detailed explanation of the system.
026 - 4. (LATO) List of applicable technical order.
026 - 5. Ground radar, control.
026 - 6. It is alignment procedures for AN/MSQ-77 series radar.
026 - 7. In front of the basic TO.
026 - 8. The complete change should be checked against the new listing.

027 - 1. The service manual, Chapter 2, pertaining to the specific equipment being installed.
027 - 2. Circuits and diagrams and possibly Chapter 4 of the service manual.
027 - 3. Illustrated parts breakdown.

028 - 1. Yes. Steps 15 and 16 are reversed and equipment is subject to damage as it is now written.
028 - 2. Air Force Logistics Command (AFLC).
028 - 3. Check with your supervisor first, then contact Quality Control for assistance.

CHAPTER 5

029 - 1. He or she is the executive manager of the maintenance organization, planning, scheduling, and controlling all maintenance activities.
029 - 2. Through staff agencies that are responsible for the various functions.

030 - 1. Maintenance control section.
030 - 2. It is responsible for reports, correspondence, local maintenance, directives and keypunch services.
030 - 3. To improve the overall maintenance operation by analyzing maintenance data and statistical inputs.
030 - 4. Quality Control.
030 - 5. Job Control, Material Control, and Plans and Scheduling.
030 - 6. Information concerning programs to be supported and their impact upon available resources.
030 - 7. Directs and coordinates the maintenace production effort.
030 - 8. To see that proper parts, tools, and equipment are available. To coordinate the establishment of bench stocks, prepositioned spares, special levels, and supply points. To procure TCTOs and control tools.

031 - 1. To enter accurate and complete data on AFTO Form 349.
031 - 2. A job that has a definite beginning and end.
031 - 3. TO components that have a fixed-life expectancy.
031 - 4. An item on which a study is being made to determine its life expectancy.
031 - 5. Items of equipment on which reports are required by item serial number.

032 - 1. Enter the SRD code in block 5. The information for this entry is in TO 00-20-2.
032 - 2. Only for removal and replacement of items identified by an asterisk in the WUC manual.
032 - 3. When the Form 349 is used as a dispatch form. The entry is the time that a specialist is required.
032 - 4. The manufacturer's part number.
032 - 5. When a "serially controlled" item is removed or modified.
032 - 6. The last three digits of the AFTO Form 350 tag number.

033 - 1. From the information on AFTO Form 349.
033 - 2. A brief description of the work done on the part, if the part is made serviceable. Otherwise, NRTS is entered.
033 - 3. Production Control/RPC.
033 - 4. The agency responsible for returning an item to serviceability.
033 - 5. Status change to "awaiting parts."
033 - 6. Not at all. All unserviceability tag takes care of this.

034 - 1. When an item creates two or more MICAP reportable conditions or two or more cannibalizations within a 30-day period.
034 - 2. Equipment that requires bench checking and/or repair.

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034 - 3. Supply items that are needed for replacement during forthcoming periodic inspections.
034 - 4. The removal of equipment from one end item for installation on another end item.

035 - 1. (1) To correct the same deficiencies on like equipment at other installations, (2) To recommend improvements in design, test, and modification programs.
035 - 2. Category I.
035 - 3. Report it as Category I or DULL SWORD.
035 - 4. Category II.
035 - 5. To report on work performed by contractors and specialized repair activities.
035 - 6. Because they are reportable under the TO improvement program.
035 - 7. The quality control section.

CHAPTER 6

036 - 1. Clean any greasy spots on the floor, wipe up water, and remove obstructions from the aisles and stairways.
036 - 2. Remove (1), (2), (4), and (5).
036 - 3. Separate the victim from the circuit.
036 - 4. Turn off the main switch if you can. If you can't, remove the victim from a live circuit by using nonconducting material, such as a wooden board or rope.

037 - 1. Inspecting, cleaning, and lubricating.

038 - 1. The operations section can give Maintenance Control the best time for the equipment to be shut off.
038 - 2. Technical order workcards.
038 - 3. To provide Maintenance Control with the information it needs to schedule the PMs for completion within the allotted time.

039 - 1. Discolored, burned, or cracked resistors and capacitors; loose connections; loose mounting; faulty tubes; sluggish or dirty relays; overheated transformers and motor housings; and defective insulators.
039 - 2. Toxic solvents should be used in a well-ventilated area. Insure that they will not harm thermoplastics, "doped" coils, or natural rubber.
039 - 3. By the temperature of the element after it has been operating for a while.
039 - 4. First, remove dust, dirt, and foreign particles with a vacuum cleaner or compressed air. Next, use a lintless rag and an approved cleaning solvent to remove any remaining dirt and grease spots.
039 - 5. In the applicable equipment technical orders and technical manuals.

040 - 1. Moisture and heat.
040 - 2. Crosstalk and flashover can occur when moisture provides electrical leakage paths.
040 - 3. Moisture present when different metals have different potentials.
040 - 4. Coat equipment with an approved lacquer or varnish.

041 - 1. Items b, c, and d should be checked.
041 - 2. Compare data taken over an extended period of time.

042 - 1. Wooden-handle screwdrivers can absorb moisture, which breaks down their insulating properties.
042 - 2. Your own initiative.
042 - 3. Because each problem differs from previous problems in some respect.
042 - 4. a. Troubleshooting.
b. Safety precautions.
c. Safety precautions.
d. Troubleshooting.
e. Repair.
f. Circuit alignment.
g. Performance testing.

043 - 1. a. Class V.
b. Class II.
c. Class IVB and Class IV.
d. Class IVA.
e. Immediate action.
f. Urgent action.

044 - 1. Any three of the following:
a. Any item or condition that may affect the well-being or safety of personnel.
b. Poor equipment performance, short equipment life, or early part failures.
c. A difficulty in removing or installing certain components, units, or parts, which can be remedied by a change in procedures.
d. Repeated equipment failure caused by failure of one or more parts of the same type or make.
044 - 2. a. Inventory the kit.
b. Read the TCTO instructions. Make sure you understand them.
c. Check the TCTO to find out when the work must be completed.
d. Prepare for the job.

CHAPTER 7

045 - 1. The 60:40 and 63:37 solders.
045 - 2. 63:37 solder.
045 - 3. Used to remove oxidation from the metal surfaces to be soldered.
045 - 4. Corrosive fluxes will eat away the metal and destroy the electrical connection.

046 - 1. Because of a controllable heat output.
046 - 2. Bending component leads without nicking, scraping, or damaging the lead or component.
046 - 3. A pencil-style typewriter eraser.
046 - 4. To lift the ends of wires from terminals during desoldering.

047 - 1. Higher quality work, less time required to complete the task, and improved worker safety.
047 - 2. Wiping the tip with a rag or canvas pad.
047 - 3. To eliminate the possibility of electrical shock.

048 - 1. The action of molten solder on metal is like the action of water on salt. The solvent or intermetallic solution action chemically dissolves part of the metal surfaces to be joined and at temperatures well below the melting point of the metals being joined.
048 - 2. The soldered connection is chemical and has metal continuity. A wired or bolted connection never makes good electrical contact because of the insulating film on the surface of the metals.

049 - 1. The size, the wattage, and the shape of the tip.
049 - 2. Large.
049 - 3. The tip must not be so large that it obscures your vision or damages adjacent parts of wire insulation, but it must be the proper size and shape to produce the best solder joint.
049 - 4. Abrasive cloth.
049 - 5. While the tip is cool, clean it with a suitable file and apply heat; after the minimum temperature has been reached, apply solder to the dressed surface of the tip. Clean the tip with a damp sponge or other soft material before each connection is made.

050 - 1. If you apply heat to a rosin wick, the solder will flow readily into the rosin area, leaving the terminal to which it was previously affixed.
050 - 2. Place the wick on top of the solder joint to be removed; place the iron tip on top of the wick; when the iron melts the solder, it will flow into the wick; as the wick becomes saturated, clip off the end of the wick. Repeat these steps until you remove all the solder from the joint.
050 - 3. "Sniffing" removes the molten solder by suction.
050 - 4. The wicking method.

051 - 1. The strands should be in their original lay and there should not be any nicks in the wire or any insulation damage.
051 - 2. Approximately the diameter of the wire.
051 - 3. (1) Strip the wire carefully, using one of the recommended tools. (2) Clean off all impurities from the components to be soldered. (3) Tin the conductor to the depth required.

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052 - 1. The space between the post must be filled. Use additional tinned wire or bend the conductor into a U-shape if the double diameter of the wire will fill the space.
052 - 2. 1/32 inch.
052 - 3. The lower section.
052 - 4. Make a mechanical connection by feeding the wire through the terminal hole, using a 180° wrap and crimping the wire.

053 - 1. 1/32 inch.
053 - 2. The leakage current of some soldering irons is enough to damage transistors and small semiconductor devices.
053 - 3. Stop the soldering process and let the connection cool completely. Then repeat the soldering process as necessary.

054 - 1. Clinched and unclinched.
054 - 2. The unclinched lead termination is used in special cases where the parts are light and no stress is placed on the soldering connection.

055 - 1. First clean the conductive strip that is to be repaired (do not use a wire brush for this operation), and repair the conductor break by flowing solder over the entire break.
055 - 2. Clean the area to be repaired first. Bridge the peeling area with a bare wire, and apply solder along the entire length of the wire to bond it solidly to the conducting strip.
055 - 3. You should secure the board in a repair vise.

056 - 1. As close to the body of the defective part as possible.
056 - 2. Fashion a small loop at both ends of the new component; slip the loops over the ends of the cut defective component leads; secure the connections by bending the old leads away from the component body. Place a heat sink near the place where the lead enters the circuit board (this prevents unsoldering the old lead); solder the lead and component together. Make sure the old leads are still secured to the circuit board.

057 - 1. First clean the board with a white pencil-style typewriter eraser. The pad is clean when the whole pad shows a bright uniform appearance. The final step is cleaning the pad with a brush and alcohol.
057 - 2. The whole pad has a uniform gold-pink appearance.
057 - 3. Place the iron tip flat against the side of the component lead and center it on the pad. Form the bridge between the iron tip and the component lead. Move the solder down the lead to the end of the wire. Tin the cut in the end and then move the pad back to the soldering iron.

058 - 1. Pressure (7), vacuum (8), minichine (18).
058 - 2. As required to protect the component being worked on from stray currents.
058 - 3. Tungsten and carbon-type resistive heating elements.
058 - 4. Just enough to melt the solder.

059 - 1. Rapid drying of localized areas; accelerating the curing process for coating and bonding materials; troubleshooting.
059 - 2. Match the tip to the work; select a loose fit for proper molten solder and airflow; use the largest tip that can be safely applied. (Any three requirements discussed in text.)
059 - 3. To provide low-contact-point resistance and reduce the possibility of arcing.
059 - 4. Using the right temperature.
059 - 5. It can be used for soldering and desoldering applications when the workpiece may be damaged by high-current flow or arcing.

060 - 1. The spindle should be oiled at least each 10 hours of operation. The shaft should be oiled if any vibration is noticed.
060 - 2. The filter should be replaced as often as required to maintain full vacuum flow.

061 - 1. The amount of current that must be carried.
061 - 2. Place it into the vise with the wiring cup side up and the pins in horizontal rows. Be careful not to overtighten the vise.
061 - 3. 5/8 inch.
061 - 4. A 20-foot cable would require an outer cable housing 20 feet 4 inches long.
061 - 5. First cut the cord about 2 inches longer than the length needed to make 12 turns around the harness. Form one end of the cord into a 1-inch loop and place it flat on the harness, parallel to the wiring. Wind 12 turns tightly over this loop and, at the last turn, push the cord end through the loop that extends from under the wrap. Pull the end of the cord that was looped until the loop is about halfway under the wrap.
061 - 6. It minimizes insulation damage.
061 - 7. Lacing over the loop locks the cord tight. If the cord is laced under the loop, it will become too loose.
061 - 8. All the lacing should follow the top of the harness, and, when possible, all knots and irregularities should be out of sight when the cable is installed.
061 - 9. Wrap 4 turns of cord next to the last lockstitch. Then form a separate piece of cord into a 2-inch loop and lay it alongside the cable. Wrap 8 turns of lacing about the loop and draw the end of the lacing cord through the loop. Pull both ends of the loop carefully to draw the cord end underneath and out of the wrap. Pull the cord end tight, locking the wrap, and then cut the ends to approximately one-fourth inch.

CHAPTER 8

062 - 1. 50-volt scale, negative lead to TP2.
062 - 2. 500-volt scale, positive lead to TP2.
062 - 3. Turn the power off while connecting or disconnecting the meter; keep your hands off of the metal part of the probes; select the 1,000-volt scale; and observe the proper polarity of the leads.

063 - 1. The AC function, 250-volt scale, and either lead to TP4.
063 - 2. The AC function and the 50-volt scale.
063 - 3. 56 volts, 2,000 Hz. Due to inductive reactance.

064 - 1. Select the ohm function; select X1 range; connect the meter leads together and zero the ohmmeter; and make the measurement.
064 - 2. Select the proper scale, zero the meter, and isolate the resistor from parallel circuits.
064 - 3. To prevent placing your body's resistance in parallel with the resistance you are measuring.

065 - 1. Range 250, function DC mA.
065 - 2. The meter must be connected in series with the circuit being measured.

066 - 1. The high-input impedance, 10 megohms for DC ranges and 1 megohm for AC ranges.
066 - 2. After the preliminary settings have been made, select the DC mode; make sure that the EXT REF button is in the OUT position; short the input leads together, and read the display. If it does not read zero, you can adjust the readout for a zero reading by varying the adjustment located directly under the VDC button.
066 - 3. In the K-ohm mode, the resistance is displayed in K ohms with the decimal point in the proper position. In the 10^4K-ohm mode, the instrument displays the resistance in K ohms and the decimal is understood to be at the right of the least significant digit.

067 - 1. X-band; 8.4 to 10.0 GHz.
067 - 2. +50 dBm; all our radars can exceed it.
067 - 3. When using the signal generator function.
067 - 4. In the RF in PWR (dBm) position a direct reading of peak power, at the test set, is made from the numeric display.

068 - 1. DC level to 50 MHz.
068 - 2. AC, ground, DC.
068 - 3. INT, LINE, EXT, and EXT ÷ 10.
068 - 4. When two input signals are to be compared.
068 - 5. A TIME/DIV.
068 - 6. 0.2 microsecond/division.
068 - 7. A TIME/DIV and the DELAY-TIME MULTIPLIER control.

069 - 1. AC voltage, DC voltage, and voltage comparison measurements.
069 - 2. Two.
069 - 3. +175 volts.
069 - 4. CAL position.
069 - 5. +216 volts.

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070 - 1. The sweep speed will be multiplied by 10.
070 - 2. Some distortion of the picture will result from a nonlinear sweep.
070 - 3. CAL.
070 - 4. 300 microseconds.
070 - 5. 1.667 kHz.
070 - 6. 1-microsecond position.
070 - 7. The reference point of the reference signal is placed on a vertical grid line and the horizontal difference is measured beginning at that grid line.

071 - 1.
a. Display the two pulses on the trace.
b. Include both pulses in an intensified portion of the trace.
c. Set the first pulse on a vertical grid line; note dial setting.
d. Adjust the DELAY-TIME multiplier dial until the second pulse appears where the first pulse had been.
e. Subtract the first dial reading from the second dial reading and multiply by the delay time on A TIME/DIV switch.

071 - 2. 0.51 milliseconds.
071 - 3. Apparent magnification is 200 times.
071 - 4. .5 millisecond.
071 - 5. 1.5 microseconds.

072 - 1. That the tube is reaching the end of its normal life span.
072 - 2. True.
072 - 3. True.
072 - 4. True.
072 - 5. It becomes noisy and the emission rate decreases.
072 - 6. Place similar tubes in the circuit one at a time until you find one, with the proper characteristics, that functions correctly.

073 - 1. Dynamic mutual conductance type.
073 - 2. To test rectifier tubes used in power supplies.
073 - 3. LINE ADJUST control.

074 - 1. To test small and medium power transistors and diodes directly in or out of their circuits.
074 - 2. Six.
074 - 3. I_{CBO} (collector leakage current).

075 - 1. 39 dBm.
075 - 2. The meter was not properly warmed up, or you were holding it in your hand.
075 - 3. That it is calibrated for the frequencies you use.

076 - 1. The horizontal sweep is time per division as an oscilloscope and frequency per division as an analyzer.
076 - 2. Blank the bottom with the baseline clipper and adjust the peak for optimum display.
076 - 3. It's easy to ruin the CRT.
076 - 4. Store one and change the vertical sweep position so that there is no overlap, and store the other spectrum.
076 - 5. Set the test set input attenuation to maximum.
076 - 6. In the center.

077 - 1. To provide any signal or combination of signals required to check the performance of the TPX-42 interrogator equipment.
077 - 2. Oscilloscope, interrogator signal simulator, RF signal generator, and selective identification signal (SIS) generator.

078 - 1. Normal, normal + X, emergency, variable emergency, and identification/position (I/P).
078 - 2. 1111333311113333 (etc.).
078 - 3. SIF pulse trains, challenge/tag, reset, word A or B, and suppressor pulse.

079 - 1. Fixed 1090-MHz CW, 1070-1110-MHz sweep signal, frequency markers representing the center frequency and the ±3, ±5, ±10, and ±20 MHz points of the sweep frequency, and a sweep sync output to sync the oscilloscope.
079 - 2. Three simulated radar video pulses, active readout signals representing a specific target area, and antenna azimuth rotation data consisting of ACPs and ARPs.
079 - 3. It is a 60-MHz ± 20-MHz sweep signal.

080 - 1. 1030-MHz CW, 1010-1050-MHz sweep frequency signal, frequency markers, sweep sync, and heterodyned video.
080 - 2. To generate, mix, demodulate, and control the RF level of the signals required to test and align the interrogator transmitter and receiver equipment.

081 - 1. By selecting the required markers with the XTAL MARK (USEC) switch.
081 - 2. To the FREQ MARK IN jack in the vertical section of the oscilloscope.

082 - 1. Never connect shorted cables to the test set, doublecheck your connections, do not let the cables and probes lie on the floor, and use cables of the right length.
082 - 2. To set the controls to specified positions that will enable the technician to obtain the correct indications to perform the test procedures.

083 - 1. II.
083 - 2. Organizational.
083 - 3. I.

1984-746-037/2461 AUGAFS,AL(850027)800

AU GAFS, AL. (842570)600

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READING ACHIEVEMENT TEST	
PART I (DATE AND SCORE)	PART II (DATE AND SCORE)

ECI/CDC PARTICIPATION, ETC					
URSE NUMBER AND TITLE A	NO. OF VOLUMES B	DATE COMP (MO/YR) C	COURSE NUMBER AND TITLE A	NO. OF VOLUMES B	DATE COMP (MO/YR) C

TECHNICAL AND SUPERVISORY TRAINING			
COURSE NUMBER AND TITLE	DATE COMPL	COURSE NUMBER AND TITLE	DATE COMPL

BE–623B

Foldout 1. AF Form 623.

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MAINTENANCE DATA COLLECTION RECORD

OMB NO. 21-R0227

1. JOB CONTROL NO.	2. WORKCENTER	3. I.D. NO./SERIAL NO.	4. MDS	5. SRD	6. TIME	7. PRI	8. SORTIE NO.	9. LOCATION

10. ENG. TIME	11. ENGINE I.D.	12. INST ENG TIME	13. INST. ENG. I.D.	14.	15.	16.	17. TIME SPC RFQ	18. JOB STD.

19. FSC	20. PART NUMBER	21. SER. NO./OPER. TIME	22. TAG NO.	23. INST. ITEM PART NO.	24. SERIAL NUMBER	25. OPER. TIME

ACT. LINE	A TYPE MAINT	B COMP POS	C WORK UNIT CODE	D ACTION TAKEN	E WHEN DISC	F HOW MAL	G UNITS	H START HOUR	I STOP DAY	I STOP HOUR	J CREW SIZE	K CAT LAB	L CMD ACT ID	M SCH CODE	N AFSC/EMPLOYEE NUMBER
1															
2															
3															
4															
5															

26. DISCREPANCY

27. CORRECTIVE ACTION

28. RECORDS ACTION

AFTO FORM JAN 80 349 PREVIOUS EDITION WILL BE USED.

29. PARTS REPLACED DURING REPAIR(SUBASSEMBLIES REPAIRED/REPLACED)

LINE NO.	A FSC	B PART NUMBER	C WORK UNIT CODE	D REF SYMBOL	E HOW MAL	F QTY.

30 CONTINUATION FROM BLOCK .....

Foldout 2. AFTO Form 349, Maintenance Data Collection Record.

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AFTO FORM 350
OCT 82

PREVIOUS EDITION
WILL BE USED

OMB NO. 0701-0014

REPARABLE ITEM PROCESSING TAG

1. JOB CONTROL NO.	2. ID / SERIAL NO.	3. TM	3A. SRD	4. WHEN DISC
5. HOW MAL	6. MDS	7. WORK UNIT CODE	8. ITEM OPER TIME	9. QTY.
10. FSC	11. PART NUMBER			
12. SERIAL NUMBER	13. SUPPLY DOCUMENT NUMBER			

14. DISCREPANCY

15. SHOP USE ONLY

15A. CMD / ACT ID	15B. SHOP ACTION TAKEN

TAG NO. 222371 AFTO 350 PT. I

16. SUPPLY DOCUMENT NUMBER

17. NOMENCLATURE

18. PART NUMBER	18A. WORK UNIT CODE

19. NSN

20. ACTION TAKEN	21. QTY.	22. RPC. USE ONLY

TAG NO. 222371 AFTO 350 PT. II

FRONT

★ GPO 661-600

WARNING

Unauthorized persons removing, defacing, or destroying this tag (or label) may be subject to a fine of not more than $1,000 or imprisonment for not more than one year or both. (18 USC 1 36 1)

REPAIR CYCLE DATA

23. NSN	24. SRAN CODE
25. TRANSPORTATION CONTROL NUMBER	

STATUS CHANGED TO

26. SERVICEABLE

27. CONDEMNED

28. SUPPLY INSPECTOR'S STAMP

29. BASE REPAIR CYCLE DATA		YR	JULIAN DAY	TIME
DATE REMOVED	REC'D BY RPC			AWM
TO:				
TO:				AWP
TO:				
TO:				
TO:				
DATE COMPLETED				

BACK

NEO13-489

Foldout 3. AFTO Form 350, Repairable Item Processing Tag.

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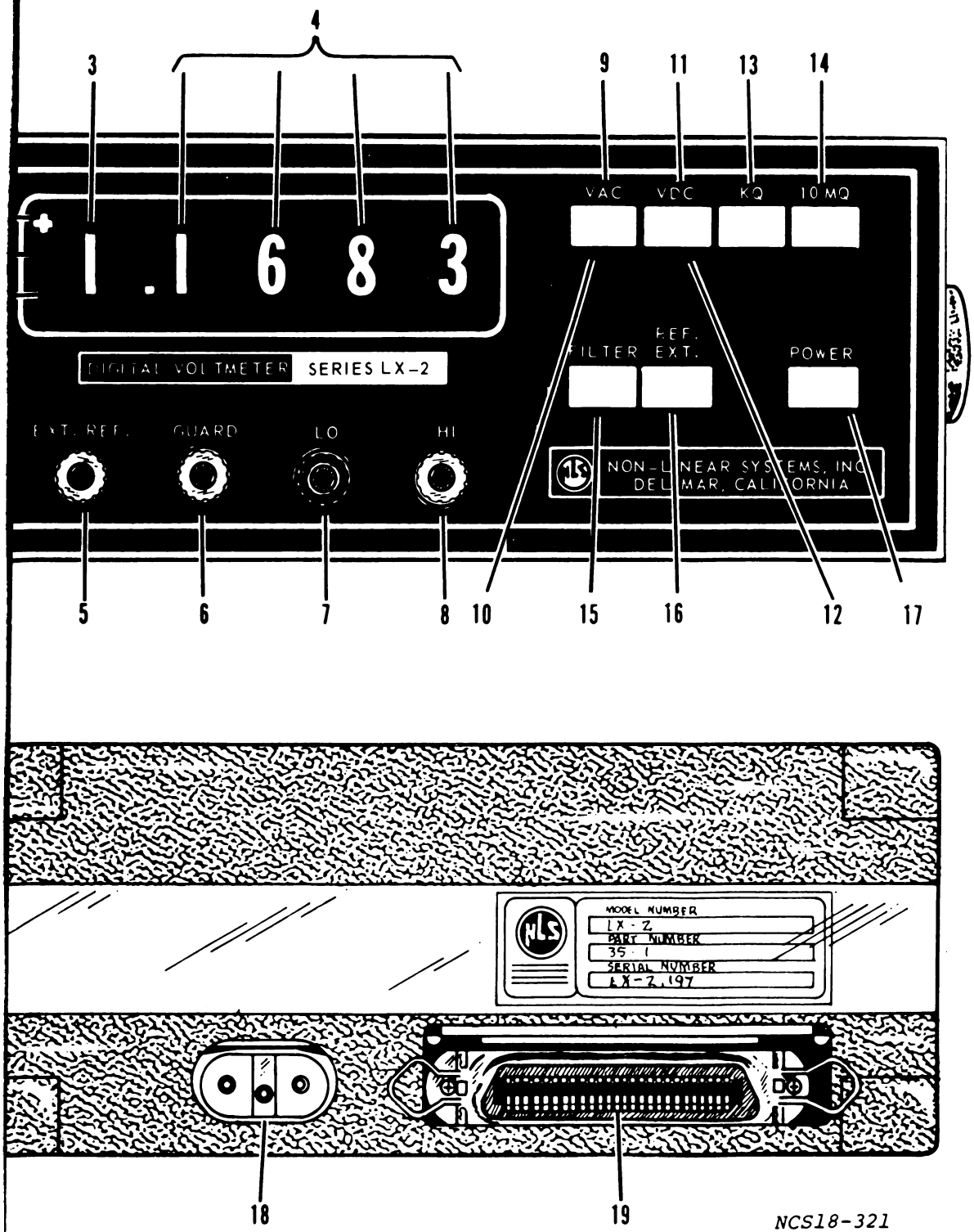

Foldout 4. LX–2, front and rear views.

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UNIVERSITY OF MINNESOTA
wils.gov
D 301.26/17-2:30353 01 8406
Hutchinson, Kenneth J.
Automatic tracking radar specialist (AFS
3 1951 002 923 712 8

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